CONNECTICUT DEPARTMENT OF TRANSPORTATION

BRIDGE LOAD RATING MANUAL

Questions and inquires for this Manual please contact: DOT.BridgeRating@CT.gov

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TABLE OF CONTENTS

CONNECTICUT DEPARTMENT OF TRANSPORTATION

DEFINITIONS

As-Built Plans (As Constructed) – Plans that show the state of the bridge 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.

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

Box Culvert – Reinforced concrete cast-in-place and precast box culverts under fill, both three and four-sided.

Condition Rating – The result of the assessment of the functional capability and the physical condition of bridge components by considering the extent of deterioration and other defects.

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

Crossbeam (Bent Cap) – A transverse beam supporting longitudinal girders at a bent.

Fracture Critical Member – Steel member in tension, or with a tension element, whose failure could cause a portion of or the entire bridge to collapse.

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

Limit State – A condition beyond which the bridge 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 live load carrying capacity of an existing bridge.

Load Rating File Set – The complete collection of documentation, preliminary, analysis, and summary files that make up the Load Rating, stored in a bridge-numbered folder.

Load Rating Report – The stamped, calculation book (electronic pdf) for the Load Rating.

Load Rating Section – The Load Rating specialist group that is part of the Office of Bridge Design in the Connecticut Department of Transportation Engineering Division.

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

Metal Pipe – Steel or aluminum structures that are defined by a pipe with a single radius equivalent to the span length throughout.

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

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

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 bridges located on or over all public roads.

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 absolute maximum live load that the structure can be subjected to, for limited passages of the load.

Pier – A substructure unit with one column or shaft supported by a footing 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.

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.

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

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 Vehicles, especially on short spans.

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

Terminal Development Length – The distance beyond the theoretical cover plate end to allow terminal development of the plate.

Theoretical End of Cover Plate – For partial length cover plates, this is the section at which the stress in the flange without that cover plate equals the allowable stress exclusive of fatigue considerations. For evaluation, this is the length of the cover plate minus the terminal development length at each end of the cover plate.

Year Built - Refers to the date of original construction of the superstructure and substructure.

Year Rebuilt – Refers to the date of major structural changes but the original substructure is in place.

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
CTDOT – Connecticut Department of Transportation
FHWA – Federal Highway Administration
LFD – Load Factor Design
LFR – Load Factor Rating
LRFD – Load and Resistance Factor Design
LRFR – Load and Resistance Factor Rating
MBE – Manual for Bridge Evaluation
NBI – National Bridge Inventory
DW – Dead load of Wearing Surface and Utilities
DC – Dead load of Structural Components and Nonstructural Attachments
LL – Live Load
FEM - Finite Element Model
FEA - Finite Element Analysis
LLDF – Live Load Distribution Factor
MPF – Multiple Presence Factor

CHAPTER 1 GENERAL

1.1 Purpose

The primary mission of the Connecticut Department of Transportation 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 task for a bridge inventory to be in a good state of repair is the knowledge of each bridge'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 structure in the State on the National Bridge Inventory has an associated load rating in accordance with the most recent *AASHTO Manual for Bridge Evaluation*.

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 and/or errata. The CTDOT Bridge Load Rating Manual 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 CTDOT personnel involved in load rating and bridge posting. In addition, consultants performing load ratings for CTDOT are required to follow the guidance contained herein. 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 CTDOT Load Rating Section.

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 in 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 disagree with the most recent MBE, the guidance in this Manual shall be followed. 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 is a living document in that changes will be issued as warranted because of changes in policy, loadings, or evaluation. The most recent version of this Manual, working template files, and example Load Rating Reports are located at the CTDOT Load Rating Website.

1.3 Methodology

LRFR shall be the only method of rating accepted for submittal. Exceptions must be approved by the CTDOT Load Rating Section prior to beginning the report. Exceptions will only be granted for evaluation of material or geometry that is not currently included in the most recent LRFD or MBE.

Judgment Ratings will only be considered if the following conditions are met when

- The structure is concrete
- All avenues locating plans are exhausted. This includes but not limited to design plans, shop drawings, working drawings and as-built plans stored with the department, design engineer, precasters and contractors.
- The structure is buried and does not meet the requirements to be coded per Article 10.1.1

1.4 Requirements to Perform a Load Rating Analysis

Each occurrence described in this Section shall require a Load Rating Report, completed in accordance with this Manual.

1.4.1 Structures in Projects

1.4.1.1 New structure or superstructure replacement

1.4.1.1.1 New structures and new elements, components and members of existing structures that undergo rehabilitation, such as superstructure replacement.

1.4.1.2 Major rehabilitation

1.4.1.2.1 Elements, components, and members of existing structures that undergo major rehabilitation, such as deck replacement, structural steel repair or structure widening.

1.4.1.3 Minor rehabilitation

1.4.1.3.1 Existing structures that undergo minor rehabilitation, such as increased overlay thickness and expansion joint replacement.

1.4.1.4 Preservation work

1.4.1.4.1 Existing structures that undergo preservation that affects permanent loading shall require a completed Load Rating Report that represents the structure's new condition.

1.4.1.5 Any additional occurrences from Article 1.4.2 below that happen during a project.

1.4.2 Structures Outside of Projects

1.4.2.1 Change in Condition

1.4.2.1.1 Where deterioration or impact damage may cause a change in the structural capacity of a primary member.

1.4.2.2 Change in Permanent Load

1.4.2.2.1 Where the most recent inspection report shows the addition of new or relocated dead loads, such as utilities or protective fencing, moving a barrier, or where previously reported dead loads have increased, such as an increase in overlay thickness.

1.4.2.3 Permit Analysis

1.4.2.3.1 Where the main purpose of completing a Load Rating Report on the structure is for permitting of oversize/overweight vehicles.

1.4.2.4 No Previous Load Rating on File

1.4.2.4.1 This applies to structures where the sole reason for performing a load rating analysis is that no previous load rating is on file with CTDOT or when an ASR, LFR, or Judgment Rating is upgraded to LRFR.

1.5 Members for Evaluation

1.5.1 Decks

1.5.1.1 Open and concrete filled steel grid decks

1.5.1.2 Corrugated metal bridge planking (Deck pans, not SIP forms)

1.5.1.3 Timber decks

1.5.1.4 Steel cantilever sidewalk supports located on the outside of through plate girders and trusses

1.5.1.5 Concrete decks with longitudinal post tensioning

1.5.1.6 Reinforced concrete decks shall only be evaluated if the deck condition rating annotated in the most recent Inspection Report corresponds to poor or worse.

1.5.2 Superstructure

1.5.2.1 Girders, beams, and stringers

1.5.2.2 Floorbeams

1.5.2.3 Trusses

1.5.2.4 Open spandrel arches

1.5.2.5 Prestressed concrete adjacent deck units

1.5.2.6 Slabs

1.5.2.7 Rigid frames and arches

1.5.2.8 Critical connections as defined in Article 6.8

1.5.2.9 Diaphragms and cross frames of curved structures and structures with a support skewed greater than 30 degrees

1.5.3 Substructure

1.5.3.1 Pier caps (Steel and timber)

1.5.3.2 Columns (Steel and timber)

1.5.3.3 Bents (Steel and timber)

1.5.3.4 Concrete piers and bents

1.5.3.4.1 Special geometry or configuration (e.g. long cantilever cap) shall only be rated at the discretion of the Load Rating Section.

1.5.3.4.2 Shall be evaluated only if the condition rating of the member annotated in the most recent Inspection Report corresponds to poor or worse.

1.5.4 Culverts

1.5.4.1 Structure length (BRI-19 item 49) is 6 feet or greater.

1.6 Responsibilities of the Load Rating Section

1.6.1 Perform Load Ratings

1.6.1.1 Perform load ratings and complete load rating reports in accordance with AASHTO and the CTDOT Bridge Load Rating Manual.

1.6.2 Perform Load Rating Reviews

1.6.2.1 Conduct quality checks of Department and consultant load rating reports in accordance with AASHTO and the CTDOT Bridge Load Rating Manual.

1.6.3 Documentation

1.6.3.1 Enter the structure's inventory and operating rating factors to the web-based application, Bridge Inventory (SIS and SMS).

1.6.3.2 Upload completed load rating reports, executable files, and back-up files to the Bridge folder on ProjectWise.

1.6.3.3 Maintain the Department's AASHTOWare database.

1.6.3.4 Maintain a database of searchable load rating results.

1.6.4 Posting Meetings

1.6.4.1 Initiate Posting Meetings for structures with low rating results.

1.6.5 Load Rating Manual

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

1.7 System of Units

English System of Units shall be used in the Load Rating Report; however, International Units may be used if the referenced plans use International Units. For the Load Rating Summary Sheet use the English System of units.

CHAPTER 2 LOADS FOR EVALUATION

2.1 Dead Loads

2.1.1 DC and DW

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

2.1.1.1.1 Compacted sand, silt, and clay shall have a unit weight of 0.125 kcf in the absence of more precise information

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

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

2.1.1.2.1 When the wearing surface thickness cannot be determined from inspection reports, the thickness in the plans shall be used in analysis. If no plans are available, assume a 5 inch wearing surface thickness. This does not relieve the Load Rater from analyzing the structure with a thicker wearing surface if report photos indicate that the thickness is greater than this section assumes.

2.2 Load Factors

2.2.1 Wearing Surface

2.2.1.1 The wearing surface thickness is only considered to be field measured if core samples are taken across the width of the deck and the average depth is used in analysis. Otherwise, the load factor γ_{DW} shall be taken as 1.5.

2.3 Transient Loads

2.3.1 Longitudinal Braking Forces

2.3.1.1 The effects of longitudinal braking forces shall not be considered unless specifically requested by CTDOT Load Rating Section.

2.3.2 Application of Vehicular Live Load

2.3.2.1 See Chapter 4 of this Manual for CTDOT required truck models.

2.3.2.2 The alternate load rating method of placing truck loads only within the striped lanes is not a CTDOT approved analysis method unless approved by the Load Rating Section prior to starting this method of analysis.

2.3.2.3 Curbs less than 6 inches high above the wearing surface shall be considered mountable and vehicular traffic shall be placed transversely without restriction from the curb.

2.3.3 Dynamic Load Allowance: IM

2.3.3.1 The dynamic load allowance used in analysis shall be 33% for all vehicle axles except the CT-TLC Permit Vehicle, which shall be analyzed without a dynamic load allowance applied. Use of a dynamic load allowance other than that specified herein must be approved by the CTDOT Load Rating Section.

2.3.4 Pedestrian Live Loads: PL

2.3.4.1 Sidewalks with non-mountable curbs or barriers between the walkway and the roadway shall be loaded in accordance with *LRFD Article 3.6.1.6*, but not concurrently with vehicular live load.

2.3.4.1.1 Pedestrian live load shall not be considered where mountable curbs, as described in Article 2.3.2.2, are present, since it will be loaded with vehicular live load instead.

2.3.5 Wind Loads: WL and WS

2.3.5.1 Wind loads shall not be considered unless specifically requested by the CTDOT Load Rating Section.

2.3.6 Temperature Effects

2.3.6.1 Temperature effects shall not be considered.

2.3.7 Creep and Shrinkage: CR and SH

2.3.7.1 For typical bridges creep and shrinkage effects shall not be considered.

2.3.7.2 For more complex bridges, the creep and shrinkage effects need to be accounted for at the discretion of the Load Rating Section when determining dead load effects.

CHAPTER 3 STRUCTURAL ANALYSIS

3.1 Approximate Methods of Structural Analysis

3.1.1 Single Line Girder

3.1.1.1 A single line girder analysis analyzes the member as a straight, continuous beam using influence lines. LLDF's are used to distribute the live load to the beam.

3.1.1.2 Single line girder analysis is allowed only at the discretion of the Load Rating Section.

3.1.2 Line Girder System

3.1.2.1 A line girder system analysis is a method of describing each member individually as a single line girder and additionally entering the member locations and other superstructure details (-e.g. skew and diaphragm layout) for analysis.

3.1.2.2 Linking members or analyzing a single member to represent several members can only be done if the members, the load applied to those members, and any diaphragm/cross frame positions relative to the bearing line are identical.

3.2 Refined Methods of Analysis

3.2.1 FEA

3.2.1.1 FEA evaluates a model in a virtual environment with assigned variables to simulate realistic loadings, conditions, and stresses of the structure.

3.2.1.2 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 Load Rating Section will determine the need for a FEA.

Other alternative types of analysis/methods for load rating structures are not approved for submission to the Department.

CHAPTER 4 LOAD RATING PROCEDURES

4.1 General Load Rating Equation

4.1.1 Limit States

4.1.1.1 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.

4.1.1.1.1 Strength I checks the strength and stability of a structure for the Design and Legal load cases.

4.1.1.1.2 Strength II checks the strength and stability of a structure for the Permit load cases.

4.1.1.1.3 Service I checks the $0.9F_y$ stress limit in reinforcing steel. This limit state addresses permanent deformation of reinforcing steel in R/C and P/S concrete members for permit loads.

4.1.1.1.4 Service II checks for permanent deformation of steel members.

4.1.1.1.5 Service III checks for cracking of prestressed components using an un-cracked section analysis.

4.1.1.1.6 Fatigue limit state is checked using the LRFD Fatigue Truck (See MBE Article 6A.6.4.1) in accordance with Article 6.2

4.1.1.1.7 Load factor for DW at the strength limit state may be taken as 1.25 provided that the requirements of Article 2.2.1 are met. This only applies to the load applied by the wearing surface. Other DW loads are to have a load factor of 1.5.

4.1.2 Condition Factor, (φ_c)

4.1.2.1 The condition factor shall be determined from *MBE Tables 6A.4.2.3* and *C6A.4.2.3-1* as they relate to the most recent Inspection Report.

4.1.2.1.1 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 in an inspection report, will not reduce the carrying capacity of a similar member that may be in better condition.

4.1.2.2 Deteriorated Members

4.1.2.2.1 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*.

4.1.2.3 When load rating a structure as part of a replacement or rehabilitation project, the condition factor of all new and rehabilitated members shall be 1.0.

4.1.3 System Factor, (φ_s)

4.1.3.1 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 state.

4.2 Design Load Rating

4.2.1 Design Inventory and Operating Ratings

4.2.1.1 Design Inventory and Operating Ratings are required by FHWA. These rating factors are used for comparative purposes in order to compare structures across the nation on an equal scale. These factors are recorded on the BRI Form 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 *LRFD Article 3.6.1.3*. The HL-93 geometries and axle loads shall conform to *MBE Appendix C6A*.

4.3 Legal Load Rating

4.3.1 Purpose

4.3.1.1 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 encompass groups of these vehicles are not allowed.

4.3.1.2 Routine Commercial Traffic

4.3.1.2.1 Loading shall be in accordance with *MBE Article 6A.4.4.2.1a* except that:

4.3.1.2.1.1 For negative moments at interior supports, a lane load of 0.2klf combined with two CT-L3S2 vehicles whose axle loading are multiplied by 0.75 heading in the same direction separated by 30ft shall be evaluated instead of two AASHTO Type 3-3 vehicles.

4.3.1.2.1.2 For span lengths greater than 200ft, one CT-L3S2 vehicle axle loading multiplied by 0.75 combined with a lane load of 0.2klf shall be evaluated instead of one AASHTO Type 3-3.

4.3.1.2.1.3 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 200ft or continuous spans.

4.3.1.2.2 The AASHTO Type 3, Type 3-3, and Type 3S2 Units are to be rated. Their geometries and axle loads shall conform to *MBE Appendix D6A.a*. As per 4.3.1.2.1, the AASHTO Type 3-3 axle loading multiplied by 0.75 depicted in *MBE Figures D6A-4* and *D6A-5* shall be replaced by the CT-L3S2 axle loading multiplied by 0.75.

4.3.1.2.3 The AASHTO H-20 and HS-20 Units shall be rated. The HS-20 Unit geometry and axle loads shall conform to *MBE Figure 6B.6.2-1*. The H-20 Unit geometry and axle loads shall be taken as the first two axles of the HS-20 Unit.

4.3.1.2.4 The CT-L3S2 shall be rated. Its geometry and axle loads shall conform to **Figure 4.1** below.

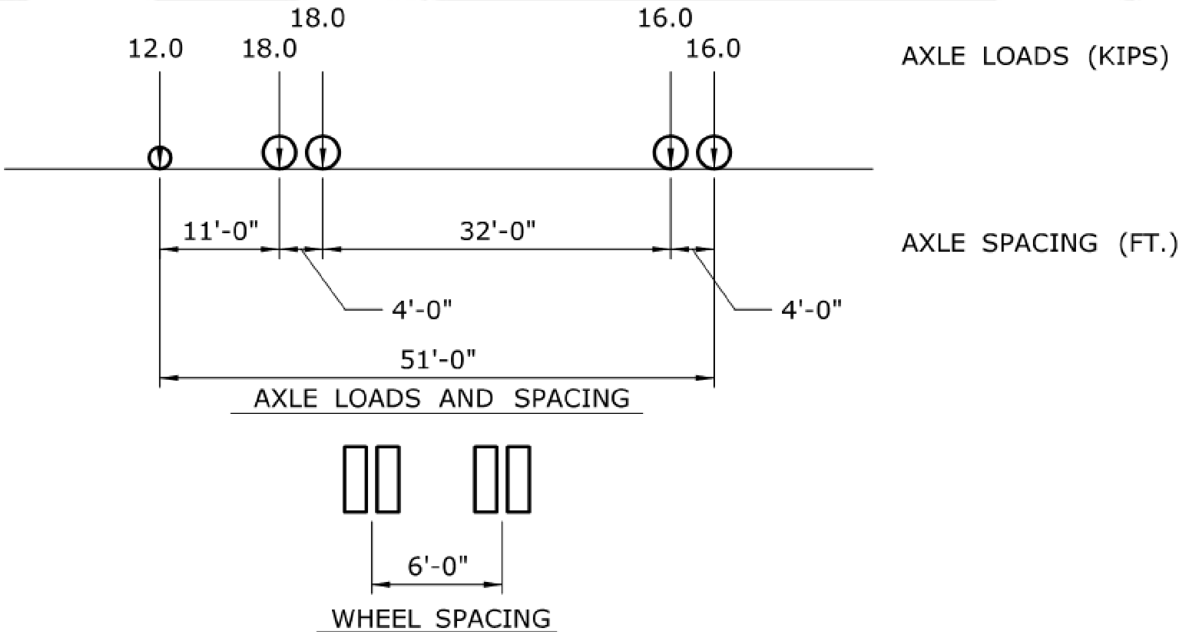


Figure 4.1

Note: CT-L3S2 represents the vehicle described in Section 14-267A(b)(8) of the CT General Statutes

<u>CT-L3S2 Legal Live Load Vehicle</u>
80 kips on 5 axles

4.3.1.3 Specialized Hauling Vehicles

4.3.1.3.1 Loading shall be in accordance with *MBE Article 6A.4.4.2.1b*. The drive axle spacing of 6 feet shall not be increased up to 14 feet, which is allowed in the MBE.

4.3.1.3.2 The AASHTO SU4, SU5, SU6, and SU7 Trucks shall be rated. Their geometries and axle loads shall conform to *MBE Appendix D6A*.

4.3.1.3.3 The CT-L73.0 shall be rated. Its geometry and axle loads shall conform to **Figure 4.2**

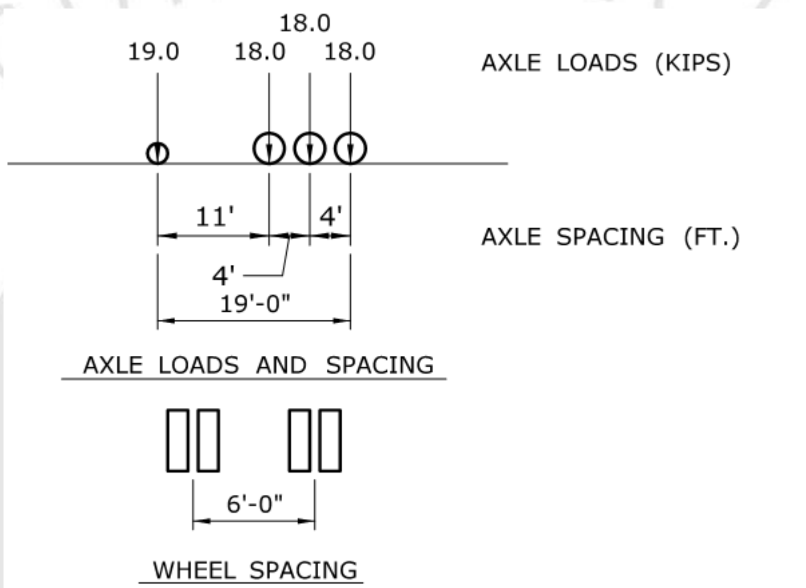


Figure 4.2

Note: CT-L73.0 represents the construction vehicle described in Section 14-269(d) of the CT General Statutes

<u>CT-L73.0 Legal Live Load Vehicle</u>
73 kips on 4 axles

4.3.2 Live Load Factors

4.3.2.1 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. For bridge and superstructure replacement projects, an ADTT > 5000 shall be used. 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 CTDOT Load Rating Section. Site specific live load factors detailed in *MBE Article C6A.4.4.2.3a* shall not be used.

4.3.3 Rating in Tons

4.3.3.1 The Legal Rating in Tons shall be determined as the Gross Vehicle Weight multiplied by the rating factor.

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

4.4 Permit Load Rating

4.4.1 Purpose

4.4.1.1 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

4.4.2.1.1 The vehicles depicted in **Figure 4.3** through **Figure 4.10** shall be rated using their corresponding geometry and axle loads.

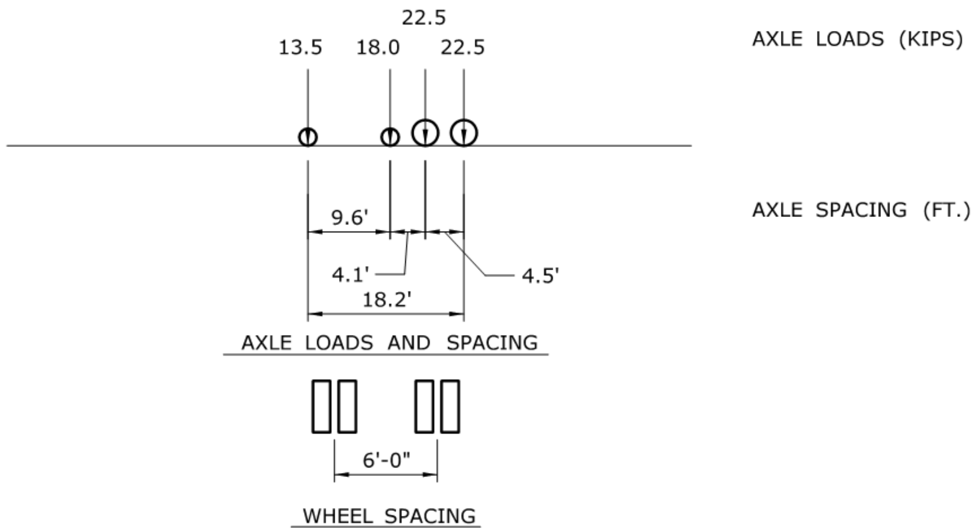


Figure 4.3

<u>CT-P76.5 Permit Live Load Vehicle</u>
76.5 kips on 4 axles

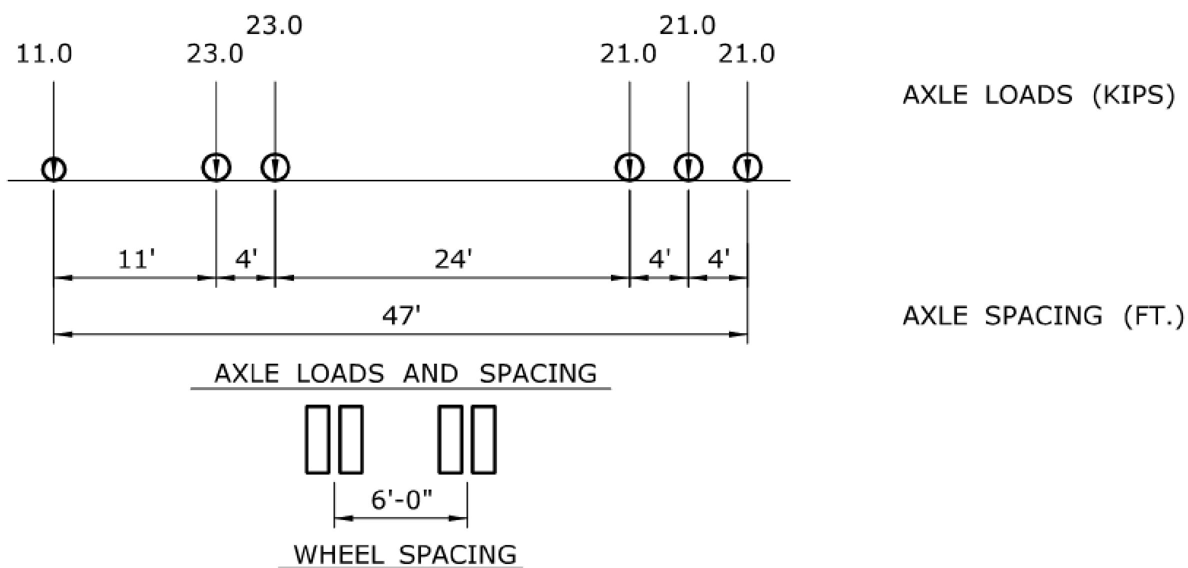


Figure 4.4

<u>CT-P120(6) Permit Live Load Vehicle</u>
120 kips on 6 axles

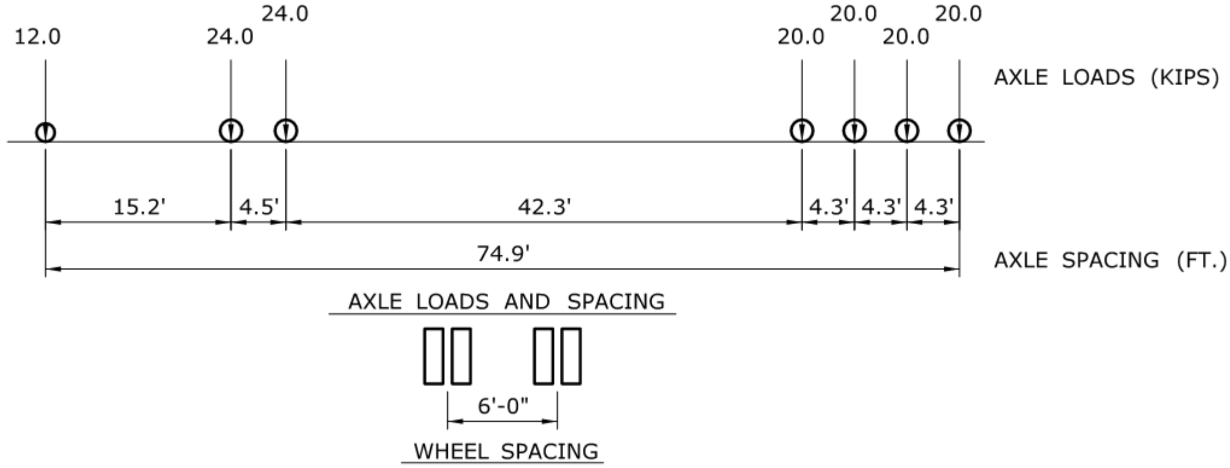


Figure 4.5

CT-P140(7)a Permit Live Load Vehicle

140 kips on 7 axles

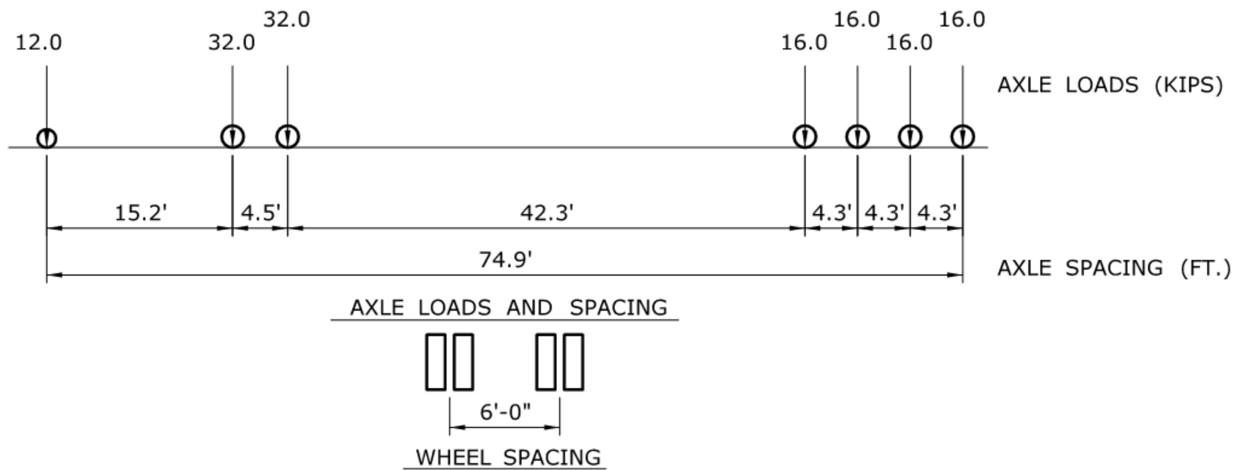


Figure 4.6

CT-P140(7)b Permit Live Load Vehicle

140 kips on 7 axles

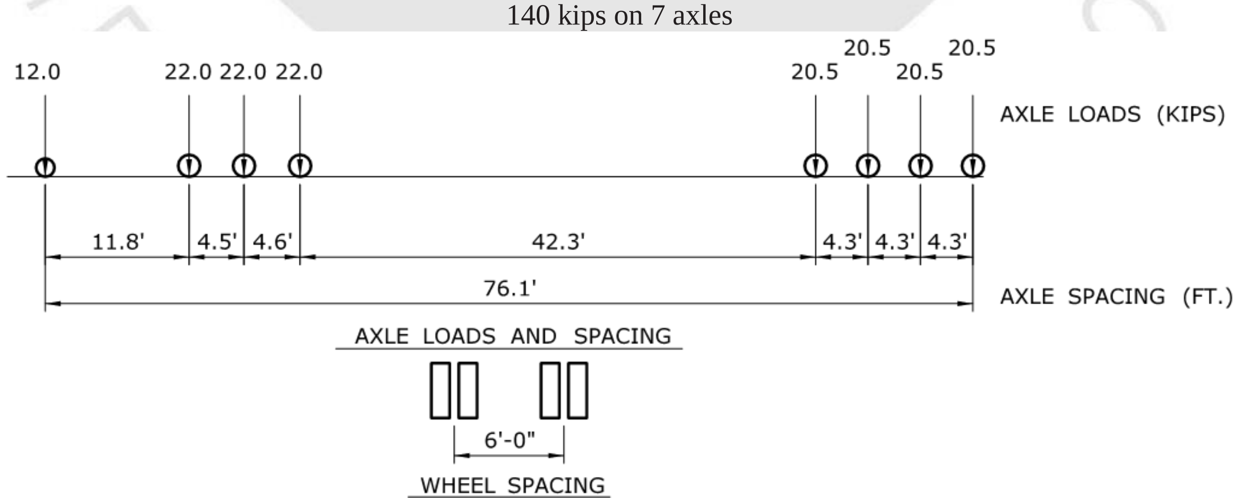


Figure 4.7

CT-P160(8)a Permit Live Load Vehicle

160 kips on 8 axles

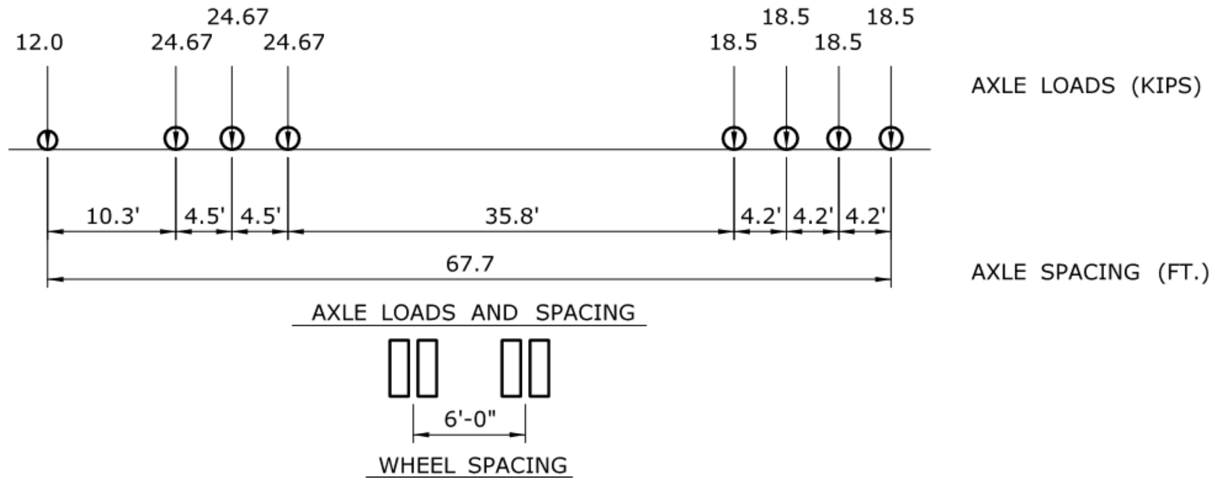


Figure 4.8

CT-P160(8)b Permit Live Load Vehicle

160 kips on 8 axles

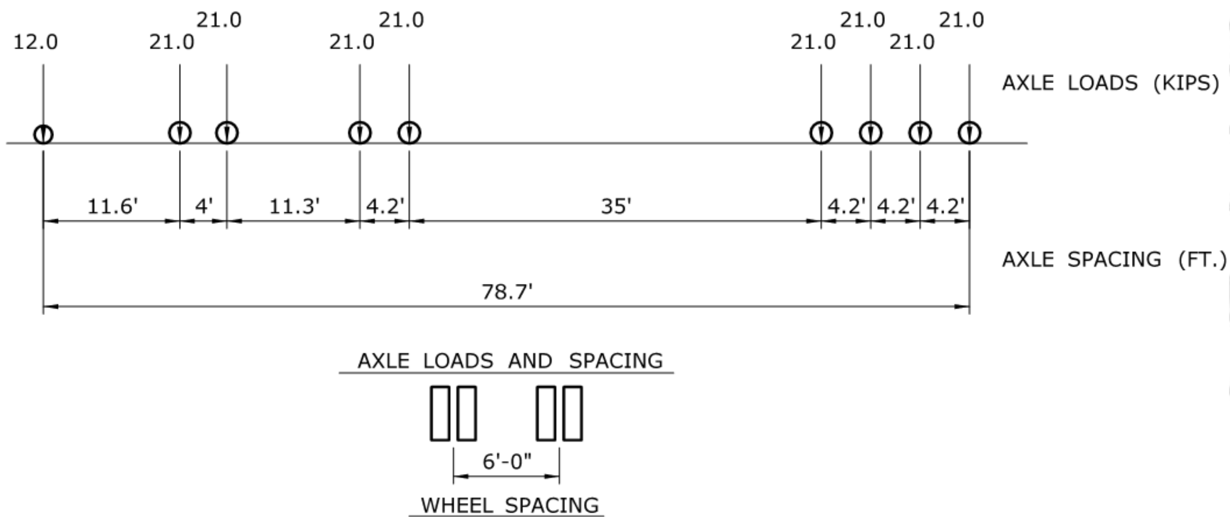


Figure 4.9

CT-P180(9) Permit Live Load Vehicle

180 kips on 9 axles

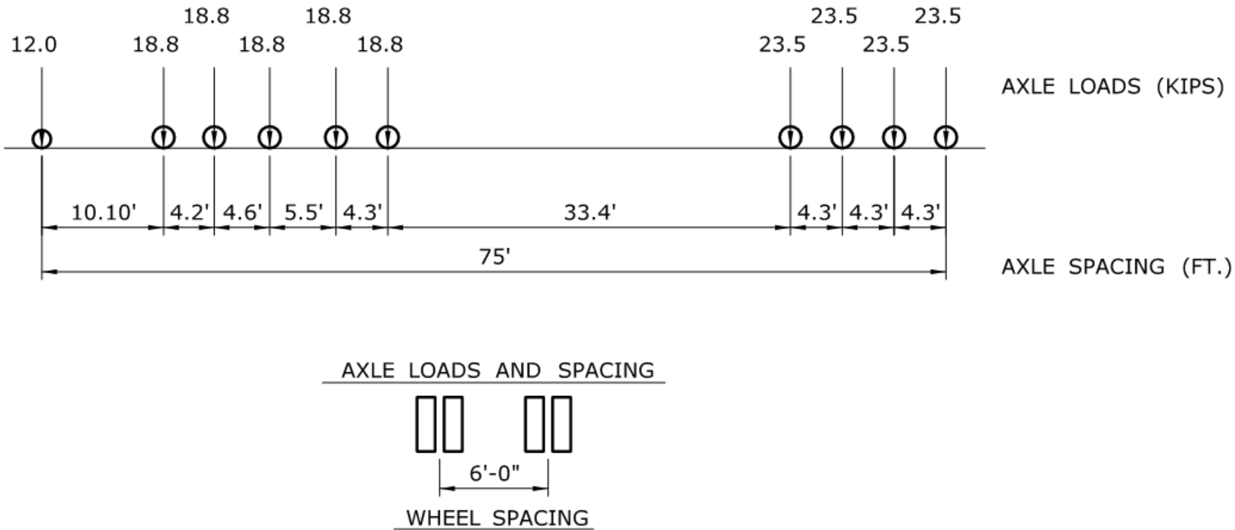


Figure 4.10

<u>CT-P200(10) Permit Live Load Vehicle</u>

200 kips on 10 axles

4.4.2.2 Special (Limited Crossing), Single-Trip, Escorted vehicle one lane distribution factor or single lane loaded.

4.4.2.2.1 The CT-P380 Permit Live Load Vehicle shall be rated. Its geometry and axle loads shall conform to **Figure 4.11**

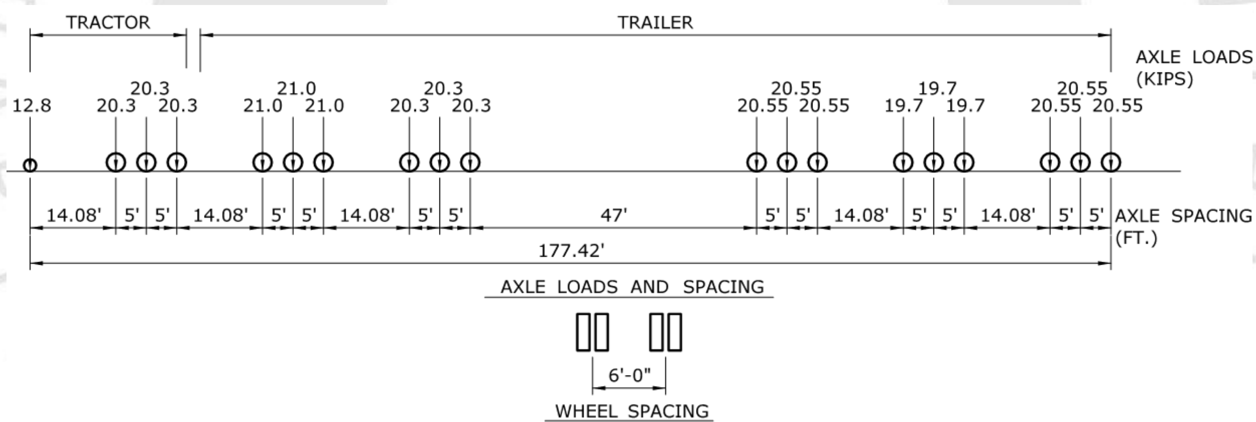


Figure 4.11

<u>CT-P380 Permit Live Load Vehicle</u>

380 kips on 19 axles

4.4.3 Special (Limited Crossing), Single-Trip, Mix with traffic one lane distribution factor or single lane loaded.

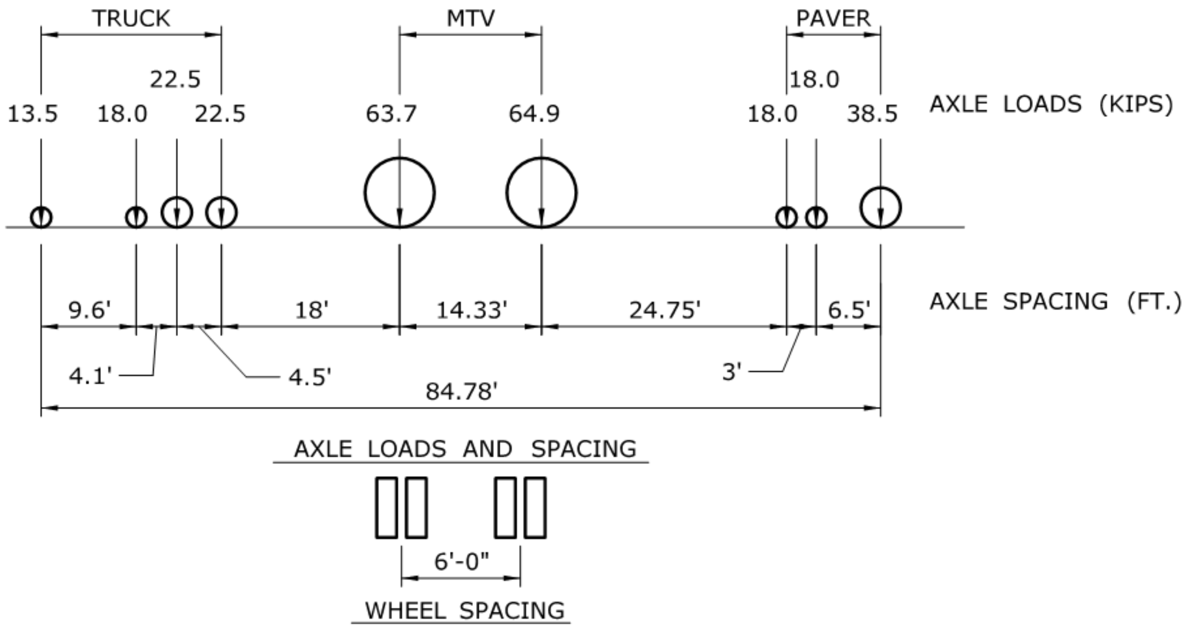


Figure 4.12
Note: TLC = Tri-load combination of vehicles in paving train

CT-TLC Permit Live Load Vehicle

279.6 kips on 9 axles

4.4.3.1.1 The CT-TLC Permit Live Load Vehicle shall be rated. Its geometry and axle loads shall conform to **Figure 4.12**.

4.4.3.1.2 The Dynamic load allowance shall conform to section 2.3.3.1

4.4.4 Live Load and Load Factors: The permit live load factors specified in *MBE Table 6A.4.2.2-1* shall be used in analysis. For bridge and superstructure replacement projects, an ADTT > 5000 shall be used.

4.4.4.1 Multiple Presence Factor

4.4.4.1.1 For all permit vehicles, the 1.2 single lane multiple presence factor shall be divided out of the LLDF if single lane distribution factors are used.

4.4.5 Rating in Tons

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

CHAPTER 5 CONCRETE STRUCTURES

5.1 Materials

5.1.1 Concrete

5.1.1.1 *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.

5.1.1.1.1 When only a class of concrete without a material strength is available in the structures records, MBE Table 6A.5.2.1-1 must be used to determine concrete strength.

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

5.1.1.2.1 The practice of increasing the unit of concrete by 0.005 kcf to account reinforcing steel as mentioned in LRFD C3.5.1 shall be used for calculating dead loads.

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

5.1.1.4 The mechanical properties of the concrete shall not be determined by material sampling without prior approval from the CTDOT Load Rating Section. If core 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.

5.1.2 Reinforcing Steel

5.1.2.1 *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

5.1.3.1 If the plans do not specifically callout strand type (e.g., “Stress-Relieved” or “Low-Relaxation) the following calculation should be performed and provided:

$$\text{If } \frac{Jacking\ Force\ per\ Strand}{Area\ per\ Strand} \leq (0.70) * (F_U) \text{ Then } Strand\ Type = Stress\ Relieved$$

$$\text{If } (0.70) * (F_U) < \frac{Jacking\ Force\ per\ Strand}{Area\ per\ Strand} \leq (0.75) * (F_U) \text{ Then } Strand\ Type = Low\ Relaxation$$

5.2 Legal Load Rating and Permit Load Rating

5.2.1 Service Limit State

5.2.1.1 Permit Load Rating

5.2.1.1.1 *MBE Table 6A.5.4.2.2b-1*, Yield Strength of Pre-stressing Steel, shall be used only when the yield strength of the prestressing strand cannot be discerned from available records.

5.3 Assumptions for Load Rating

5.3.1 Rebar with section loss shall have a reduced area as per that shown on the inspection report. If the program being used for analysis requires rebar to be designated by number, it is permissible to take the next lowest numbered bar in relation to the reduced area of reinforcing.

5.3.2 Exposed prestressing strands shall be considered still effective if only surface rust is noted on the inspection report.

5.3.3 Any exposed prestressing strand with deterioration leading to section loss, separation, or wires being fractured shall be discounted in the load rating analysis.

5.4 Evaluation for Shear

5.4.1 Rating for shear shall be performed for all rating trucks.

5.4.2 Shear resistance of non-prestressed members may be determined by the Simplified Procedure as described in *LRFD Article 5.8.3.4.1*. However, if the shear load rating results are low for any required loading condition, the General Procedure described in *LRFD Article 5.8.3.4.2* shall be used.

5.4.3 Longitudinal reinforcing requirement shall be checked in accordance with *LRFD Article 5.8.3.5* for negative moment regions. The requirement shall not apply to positive moment regions.

5.5 Concrete Bridges with Unknown Reinforcement

5.5.1 See Article 1.3 on assignment of Judgment Ratings

5.6 Rating of Segmental Concrete Bridges

5.6.1 Design-Load Rating

5.6.1.1 The number of live load lanes shall be determined from *MBE Article 6A.2.3.2* and not based on the number of striped lanes.

5.6.2 Service Limit State

5.6.2.1 Legal Load Rating – The number of live load lanes shall be determined from *MBE Article 6A.2.3.2* and not based on the number of striped lanes.

5.6.2.2 Permit Load Rating – The number of live load lanes shall be determined from *MBE Article 6A.2.3.2* and not based on the number of striped lanes.

5.6.3 System Factors

5.6.3.1 For box girder bridges with three or more webs, the values of *MBE Table 6A.5.13.6-1* shall be increased by 0.10.

5.7 Prestressed Concrete Structures

5.7.1 Prestress losses

5.7.1.1 Losses shall be calculated using the AASHTO Approximate method for composite structures. The values listed below shall be used if actual values cannot be discerned from available records:

5.7.1.1.1 Service life: 75 years

5.7.1.1.2 Transfer time: 24 hours

5.7.1.1.3 Age at time of deck placement: 28 days old

5.7.1.1.4 Humidity: 80%

5.7.1.2 If low ratings result from the Approximate Method, the AASHTO Refined Method shall be used if applicable.

5.7.1.3 The AASHTO Refined Method shall be used for non-composite members.

5.7.1.4 PCI or lump sum methods are not permitted.

5.8 Continuity Diaphragms

5.8.1 Any concrete structure which meets the requirements of *LRFD Article 5.14.1.4* to make simple span precast members act as continuous can be analyzed for rating as such. If the age of a girder when continuity was established is not clearly specified; however, the structure was clearly designed to be made continuous, that girder shall still be analyzed as continuous for transient loads.

5.9 NEXT Beams

5.9.1 Distribution factors for NEXT beams type D and F beams should follow the guidance provided on PCI Northeast's website.

CHAPTER 6 STEEL STRUCTURES

6.1 Materials

6.1.1 Mechanical Properties

6.1.1.1 *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 load rating engineer 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*. A similar process should be followed for pins and wrought iron with unknown material properties using the recommended values in *MBE Articles 6A.6.2.2* and *6A.6.2.3*, respectively.

6.1.1.2 The mechanical properties of the structural steel shall not be determined by material sampling without prior approval from the CTDOT Load Rating Section. 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

6.2.1.1 Fatigue-prone details (Category C 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*.

6.2.1.2 Partial Length Cover Plates

6.2.1.2.1 Peened welds

6.2.1.2.1.1 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*.

6.2.1.2.2 Fatigue Analysis Location

6.2.1.2.2.1 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

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

6.3.2 For localized section loss to webs near bearing stiffeners – The effects of steel yielding shall be evaluated using the effective section described in *LRFD Article 6.10.11.2.4b*.

6.3.3 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 *LRFD Appendix D6.5*.

6.3.3.1 Low rating results shall be included as a tabularized output including: span, girder, location, loading, loading description, limit state, rating factor and tonnage after the comments section of the Load Rating Report, but shall not be reported as the governing failure mechanism on the summary sheet.

6.3.3.2 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.

6.3.3.3 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.

6.3.3.4 When stiffeners are present, the resistance of the column section composted of the stiffeners and web for localized web yielding shall adhere to *LRFD 6.10.11.2.4b*.

6.3.3.5 The web thickness used in analysis shall be the average thickness at the base of the web within the limits shown in **Figure 6.1**

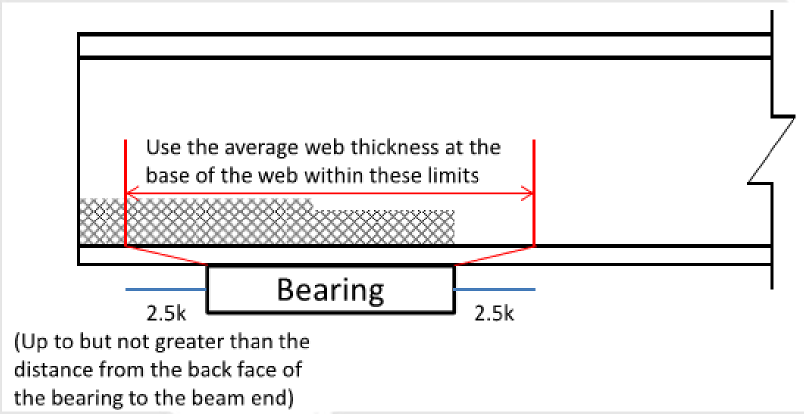


Figure 6.1

6.3.3.6 An approved Excel file for beam ends with web loss is available at the Bridge Design Website.

6.3.4 When analyzing section loss to gusset plates, the methods described in *MBE Appendix A11* 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

6.4.1 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 The inclusion of the f_l term in *LRFD Design Equations 6.10.4.2.2-2* and *6.10.4.2.2-3* 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 the f_l term in analysis.

6.5.1.2 The provisions of *LRFD 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 *LRFD Article A6.1* are satisfied.

6.5.1.3 The provisions of *LRFD 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 *LRFD Article B6.2* are satisfied.

6.5.2 Composite Sections

6.5.2.1 Compact, composite sections shall be analyzed at the plastic moment capacity.

6.5.3 Non-composite Sections and Sections with unknown mechanical shear connector details

6.5.3.1 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 Inspection report.

6.5.3.2 Determine if composite action exists: The following guidance is from NCHRP Research Results Digest, November 1998 – Number 234, *Manual for Bridge Rating Through Load Testing*.

6.5.3.2.1 For encased I-sections with no sign of cracking, rust, or separation along the steel-concrete interface indicated in the most recent Inspection Report, the encased I-section shall be assumed to act as a composite section at the service and fatigue limit states. The encased I-section shall initially be assumed to act as non-composite at the strength limit state. If low flexure ratings result, the encased I-section must be evaluated for composite action without mechanical shear connection. If the encased I-section satisfies the requirements of **Equation 6-1**, it shall be considered composite at the strength limit state.

6.5.3.2.2 For steel I-sections in flexure with concrete decks and unknown composite action, the I-section shall initially be assumed to act as non-composite. If low flexure ratings result, the I-section must be evaluated for composite action without mechanical shear connection provided that there is no sign of cracking, rust, or separation along the steel-concrete interface indicated in the most recent Inspection Report and that the requirements of **Equation 6-1** are satisfied. If the top flange is not partially or fully encased, use a maximum interface shear stress across the width of the top steel flange, ρ_h, of 70 psi instead of 100 psi.

$$\rho_h = \frac{p_h}{b_f} \leq 100\ psi\ for\ encased\ concrete\ and\ 70\ psi\ for\ all\ other\ cases$$

Equation 6-1

Where:
ρ_h = Interface shear stress (psi) across the width of the top steel flange
b_f = Width (in.) of the top steel flange
p_h = Horizontal shear stress (lb/in.), calculated as follows:

$$p_h = \frac{V * b_1 * d_1 * (y - \frac{1}{2} * d_1)}{n * I_c}$$

Equation 6-2

Where:
V = Factored vertical shear force (kips)
b_1 = Effective width (in.) of the concrete slab per AASHTO
d_1 = Depth (in.) of the concrete slab
y = Distance (in.) from the top of the concrete slab to the neutral axis of the composite section for live loads
I_c = Moment of inertia (in.^{4}) of the composite section for live loads
n = modular ratio, calculated according to *LRFD Article 6.10.1.1.1b*.

*The ρ_h upper limit of 100 psi corresponds to reinforced concrete with a compressive strength f'_c, equal to or greater than 3,000 psi. An upper limit of ρ_h equals 80 psi shall be used for reinforced concrete with f'_c equal to 2,500 psi.

6.6 Partial Length Cover Plates

6.6.1 Partial length cover plates shall be evaluated over the theoretical length of the cover plate. 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 in the analysis.

6.6.1.1 If a continuous fillet weld across the end and along both edges of the cover plate or flange to connect the cover plate to the flange is present, the terminal development length, measured from the actual end of the cover plate, shall be 1-1/2 times the width of the cover plate at its theoretical end.

6.6.1.2 Alternatively, the end of the cover plate is the theoretical end if no weld across the end of the cover plate is provided and all of the following conditions are met:

6.6.1.2.1 The terminal development length is twice the width of the cover plate, measured from the actual end of the cover plate.

6.6.1.2.2 The width of the cover plate is symmetrically tapered to a width no greater than 1/3 the width at the theoretical end, but no less than 3 in. (75 mm).

6.6.1.2.3 There is a continuous fillet weld along both edges of the plate in the tapered terminal development length to connect it to the flange.

6.7 Diaphragms and Cross Frames

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

6.7.2 Lateral bracing members shall not be analyzed unless specifically requested by the CTDOT Load Rating Section.

6.8 Evaluation of Critical Connections

6.8.1 Pin and hanger assemblies shall be rated.

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

6.8.3 The connection plates of floor-system superstructure primary members shall only be load rated if section loss is indicated in the most recent inspection report.

6.8.4 Pins in trusses shall be rated.

6.8.5 Gusset plates shall be analyzed in accordance with *MBE Article 6A.6.12.6*.

6.8.5.1 Slip Resistance – In the absence of detailed information, the surface condition factor, K_s, specified in *MBE Table 6A.6.12.6.3-2* shall be taken as 0.33.

6.8.5.2 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*.

6.9 End Condition Assumptions

6.9.1 Floorbeams and stringers shall be rated assuming they are pinned at the supports.

6.9.2 Assume the distance from outside face to outside face of the stringer end connections as the lengths for analysis.

6.9.3 Truss members shall be rated assuming they have pinned connections.

6.9.4 In the absence of more detailed information, concrete encased I-sections shall be rated assuming they are pinned at the supports.

6.9.5 Steel piles shall be analyzed as fixed at a certain depth as described in LRFD Article 6.15.3.3.

6.10 Structures with Spans Greater than 200 Feet or Continuous Spans.

6.10.1 A 0.2 kip per linear foot lane load shall be applied to permit vehicles for spans greater than 200 feet and/or continuous spans to check negative moment regions. This differs from the AASHTO MBE by removing the upper 300 foot threshold as specified in article 6A.4.5.4.1.

CHAPTER 7 TIMBER STRUCTURES

7.1 Materials

7.1.1 Unknown species and grade

7.1.1.1 If the species and/or grade of wood cannot be determined by field confirmation or grade marks, the following assumptions should be made:

7.1.1.1.1 Sawn Lumber

7.1.1.1.1.1 Assume No. 1 Southern Pine.

7.1.1.1.2 Structural Glued Laminated Timber (Beams)

7.1.1.1.2.1 Assume combination 24F-1.7E.

7.1.1.1.3 Structural Glued Laminated Timber (Deck)

7.1.1.1.3.1 Assume combination 20F-1.5E.

7.2 Resistance Factors

7.2.1 Lateral Support

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

7.2.2 Wet Service Factor, C_M

7.2.2.1 Wet use conditions shall be used in analysis.

7.2.3 Flat-Use Factor, C_{fu}

7.2.3.1 The Flat-Use Factor shall not be applied to decking.

7.2.4 Deck Factor C_d

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

7.3 Limit States

7.3.1 Deflection control

7.3.1.1 Evaluation of deflection shall not be considered unless specifically requested by CTDOT Bridge Safety and Evaluation.

7.4 Evaluation of Critical Connections

7.4.1 Non-redundant members

7.4.1.1 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 POSTING COMMITTEE

The Posting committee was established to provide recommendations to the Manger of Bridge Safety and Evaluation who has the ultimate authority of deciding whether the structure must be load restricted.

8.1 Approach

8.1.1 Posting Committee Procedure

8.1.1.1 CTDOT developed a Posting Committee Procedure for the purpose of providing a uniform approach to every structure within the State's inventory.

8.1.1.1.1 The Bridge is rated and determined that it might need to be restricted from legal vehicles.

8.1.1.1.2 The Load Rating Section will either agree or disagree with the findings.

8.1.1.1.2.1 If the Load Rating Section disagrees with the evaluation they will provide comments on how the structure should be re-analyzed.

8.1.1.1.2.2 If the Load Rating Section agrees with the evaluation they will move forward with the Posting Procedure.

8.1.1.1.3 At the Posting Meeting, the Posting Committee will discuss and determine the appropriate action to be taken for the Bridge.

8.1.1.1.4 The outcome of this Procedure will provide a safe load capacity of the Bridge.

8.2 Triggers

8.2.1 When is posting required?

8.2.1.1 A structure will require posting of load restrictions when the rating factor is less than 1.0 for any legal load that travels in the State.

8.2.2 When posting is not required?

8.2.2.1 Substandard local web yielding and web crippling at the beam ends do not necessarily warrant a posting.

8.2.2.2 Service III without any evidence of distress in the field.

8.3 CTDOT Load Rating Section

8.3.1 Responsibilities

8.3.1.1 To ensure the load rating is not overly conservative, following the load rating review, feedback will be provided to the Rater for inclusion in the load rating analysis and the Load Rating Report. This could be in-house staff or consultants.

8.3.1.2 If required, initiate a Posting Meeting by issuing a memorandum to the Posting Committee with the recommended posting tonnage for the structure.

8.3.1.3 If a Posting Meeting was held, provide all feedback and comments to the Rater that performed the analysis for inclusion in the load rating analysis. This feedback might require additional analysis.

8.3.1.4 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 Posting Committee

8.4.1 Members

8.4.1.1 Load Rating Section

8.4.1.1.1 Transportation Supervising Engineer responsible for the Load Rating Section

8.4.1.1.2 Transportation Engineer 3 of the Load Rating Section responsible for the Bridge

8.4.1.1.3 The Engineer responsible for the Bridge

8.4.1.2 Bridge Safety and Evaluation

8.4.1.2.1 Manager of Bridge Safety and Evaluation

8.4.1.2.2 Transportation Supervising Engineer responsible for the Bridge

8.4.1.3 Transportation Principal Engineer of Bridge Design responsible for the Bridge

8.4.1.4 Manager of Bridge Operations

8.4.2 Responsibilities

8.4.2.1 Determine whether a more refined analysis should be performed (-e.g. FEA)

8.4.2.2 Recommend actions that can be performed (-e.g. install a positive means to move traffic away from the controlling member)

8.4.2.3 Recommend loads to be restricted from the Bridge

8.4.2.4 Recommend types of signage to be used

CONNECTICUT DEPARTMENT OF TRANSPORTATION

CHAPTER 9 SPECIAL TOPICS

9.1 Evaluation of Unreinforced Masonry Arches

9.1.1 Masonry structures are to be load rated in ASR, in accordance with *MBE Article 6A.9.1*.

9.2 Evaluation of Pedestrian Bridges

9.2.1 General

9.2.1.1 The provisions of Chapter 1 shall be followed for Pedestrian Bridges.

9.2.1.2 The load rating of pedestrian only, equestrian, light maintenance vehicle or bicycle only bridges shall follow *LRFD Article 3.6.1.6* which refers to the *LRFD guide specifications for the design of pedestrian bridges*.

9.2.2 Loading

9.2.2.1 For pedestrian bridges, a pedestrian loading of 90 psf shall be used. This loading shall be patterned to produce the maximum load effect; however, the least dimension of a loaded area shall not be less than 2 ft.

9.2.2.2 If permanent physical barriers are not provided, an H10 vehicle must be evaluated over the structure. This is to account for any maintenance vehicles or emergency vehicles that may cross the structure. This differs from the *LRFD guide specifications for the design of pedestrian bridges Article 3.2.1* by requiring the H10 vehicle for all structures regardless of structure length.

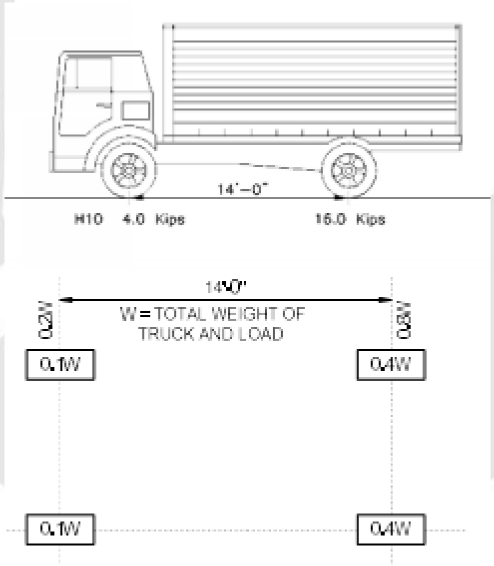


Figure 9.1

9.2.2.3 Vehicular traffic and pedestrian loads should not be applied concurrently.

9.2.2.4 The decks of all pedestrian structures shall be rated by applying a 1 kip force to a 4 inch by 4 inch patch to ensure adequate punching shear capacity to simulate equestrian loading. This loading may be omitted only if it is dimensionally implausible for a horse to cross the structure.

CHAPTER 10 RATING OF BURIED STRUCTURES

10.1 General

10.1.1 Structural Analysis

10.1.1.1 If the load rating factor for any required load condition is less than 1.0 using simplified analysis, a more refined analysis must be considered, including finite element analysis.

10.1.1.2 Where the simplified method produces low rating results and where refined methods are not suitable for use due to lack of information or other reasons, the load rating engineer shall state, in the report, the reason a more refined method of analysis was not performed.

10.1.1.3 For a buried structure where the live load effects are negligible, a load rating is not required, as determined by *MBE Article 6A.5.12.10.3a* and Article 10.1.4.2, a capacity to demand ratio shall be determined using **Equation 10-1** and the CTDOT Load Rating Summary Sheet shall show "999" for Design Inventory and Operating rating factors. The rating factors of all other loading conditions on the summary sheet shall remain blank.

10.1.1.4 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.

$$\frac{C}{D}Ratio = \frac{C}{\pm\gamma_{DC} * DC \pm \gamma_{DW} * DW \pm \gamma_{EV} * EV \pm \gamma_{EH} * EH \pm \gamma_{ES} * ES}$$

Equation 10-1

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

10.1.2 Condition Factor: φ_c

10.1.2.1 Refer to Article 4.1.2

10.1.3 Materials

10.1.3.1 Refer to Article 5.1 for concrete structures or Article 6.1 for steel structures.

10.1.4 Loads for Evaluation

10.1.4.1 Dead Loads

10.1.4.1.1 Refer to Article 2.1

10.1.4.1.2 Earth Pressure

10.1.4.1.2.1 Vertical Earth Pressure: EV

10.1.4.1.2.1.1 Refer to Article 2.1

10.1.4.1.2.2 Lateral Earth Pressure: EH

10.1.4.1.2.2.1 EH shall be determined from *LRFD Article 3.11.5.1*

10.1.4.1.2.2.1.1 In determining at-rest lateral earth pressure coefficient, k_o, assume normally consolidated soil.

10.1.4.1.2.2.1.2 In the absence of more detailed information, the Friction Angle for Dissimilar Materials, δ, shall be taken from *LRFD Table 3.11.5.3-1* assuming silty sands.

10.1.4.1.2.2.1.3 In the absence of more detailed information, assume an angle of internal friction (φ) = 30 degrees.

10.1.4.1.2.2.1.4 At rest pressure will be used for EH as per *MBE Article 6A.5.12.10.2b*.

10.1.4.1.2.3 Uniform Surcharge Loads: ES

10.1.4.1.2.3.1 In determining at-rest lateral earth pressure coefficient, k_o, assume normally consolidated soil.

10.1.4.1.2.3.2 In the absence of more detailed information, the Friction Angle for Dissimilar Materials, δ, shall be taken from *LRFD Table 3.11.5.*assuming silty sands.

10.1.4.1.2.3.3 In the absence of more detailed information, assume an angle of internal friction (φ) = 30 degrees

10.1.4.1.2.3.4 At rest pressure will be used for ES as per *MBE Article 6A.5.12.10.2c*.

10.1.4.2 Live Load Distribution

10.1.4.2.1 For single-span culverts, the effects of live load shall be neglected where the depth of fill exceeds 8 ft.

10.1.4.2.2 For multiple span culverts, the effects of live load shall be neglected where the depth of fill exceeds 10 ft.

10.1.4.2.3 For all culverts with rigid concrete pavement and a depth of fill that exceeds 5ft (including the concrete pavement and wearing surface), the effects of live load shall be neglected. The information contained in this Article is determined by the CTDOT Load Rating Section based on data presented in *Kansas Department of Transportation report, July 2013 – Number KU-12-3, Improved Load Distribution for Load Rating of Low-Fill Box Structures*.

10.1.4.2.3.1 Culverts under fill and rigid concrete shall be initially rated using the live load distribution specified in *MBE Article 6A.5.12.10.3a*. However, if the rating results are low for depths between 2ft and 5ft, the culvert shall be reanalyzed as follows: Multiply the LL Vertical Crown Pressure, P_L, determined by *MBE Article 6A.5.12.10.3a*, by a Rigid Concrete Reduction Factor, K_R, as determined by **Equation 10-2**.

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

Equation 10-2

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

10.1.4.2.4 The tire contact area for distribution purposes of all design, legal, and permit tires shall be 20 in. wide x 10 in. long.

10.1.4.3 Dynamic Load Allowance: IM

10.1.4.3.1 The dynamic load allowance for culverts shall be taken as given in *LRFD Equation 3.6.2.2-1* except for the CT-TLC Permit Loading, which shall be 0%.

10.2 Rating of Reinforced Concrete Box Culverts

10.2.1 General Load Rating Requirements

10.2.1.1 Water load on interior walls shall be neglected in load rating calculations.

10.2.2 Structural Analysis of Box Culverts

10.2.2.1 The two dimensional frame analysis described in *MBE Article C6A.5.12.3* shall be used in evaluation with its corresponding assumptions. This is a simplified method designed to provide a quick, conservative, repeatable load rating.

10.2.2.2 If the load rating factor for any required load condition is less than 1.0 using the two dimensional frame analysis, a more refined analysis must be considered. Accepted refined analysis are finite element analysis, vertical springs placed along the bottom slab, or beam on elastic foundation analysis, as described in *MBE Article C6A.5.12.3*.

10.2.2.3 Top slab corners shall be analyzed as fixed connections unless the reinforcement is designed in such a way that moment will not transfer between the walls and the top slab. In such designs, the top slab shall be modeled as simple or continuous spans pinned at one corner with rollers at the interior supports or at the other corner.

10.2.2.4 Shear resistance may be determined by the Simplified Procedure for Non-prestressed Sections described in *LRFD Article 5.8.3.4.1*. However, if the shear load rating results are low for any required loading condition, the General Procedure described in *LRFD Article 5.8.3.4.2* shall be used.

10.2.3 Loads for Evaluation

10.2.3.1 Vertical Earth Pressure: EV

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

10.2.3.1.1.1 The side fill condition shall be uncompact, which limits the soil-structure interaction factor for embankment installation (F_e) to 1.40.

10.2.3.1.1.2 When determining the coefficient (C_d) used to calculate the soil-structure interaction factor for trench installations, K_μ and K_μ’ shall equal 0.165, corresponding to the maximum for sand and gravel, in the absence of more detailed information.

10.2.3.2 Lateral Earth Pressure: EH

10.2.3.2.1 EH shall be determined from *LRFD Article 3.11.5.1*

10.2.3.2.1.1 A reduced earth pressure shall be used when calculating maximum positive moment in the top slab in accordance with *LRFD Article 3.11.7*.

10.2.3.3 Uniform Surcharge Loads: ES

10.2.3.3.1 A reduced earth pressure shall be used when calculating maximum positive moment in the top slab in accordance with *LRFD Article 3.11.7*.

10.3 Rating of Reinforced Concrete Arches

10.3.1 Evaluation of reinforced concrete arches shall be by FEA only. All other requirements of Article 10.1 and Article 10.2 shall apply.

10.4 Rating of Metal Pipes and Metal Pipe Arches

10.4.1 Structural Analysis of Metal Pipes and Metal Pipe Arches

10.4.1.1 A 2D analysis using the ring compression theory may be used for analyzing structures without perforations. Structures with section loss require the entire section being analyzed be modeled with the section loss properties.

10.4.1.1.1 Metal Pipes applied load can be modeled as a uniformly radial pressure around the pipe creating a compressive thrust in the pipe walls using the ring compression theory. Refer to *Chapter 4 of the Connecticut Drainage Manual* and the 1965 article written by the *Connecticut Society of Civil Engineers on the ring compression theory*.

10.4.1.1.2 Metal Pipe Arch analysis utilizes the ring compression theory as described in Article 10.4.1.1.1, but evaluates the thrust at the crown, thrust at the floor and the thrust at the corner as a ratio of the crown radius to the radius of the section being analyzed.

10.4.2 Loads for Evaluation

10.4.2.1 Vertical Earth Pressure: EV

10.4.2.1.1 The Vertical Arching Factor for steel structures is not given in AASHTO. It can be obtained from guidance in the *Load and Resistance Factor Design (LRFD) for Highway Bridge Substructures Reference Manual and Participant Workbook* FHWA Publication No.: FHWA HI-98-032 Article 4.5.1, figure 4-14. For flexible culverts a VAF of 1.0 shall be used and for rigid culverts a VAF of 1.5 shall be used.

10.4.2.2 Host Pipe and Grout Loads

10.4.2.2.1 For pipe liner applications it is assumed the host pipe failed. The additional load from the host pipe and the grout load must be considered.

10.4.2.3 Live loads shall be run in compliance with the MBE and this Manual.

10.4.3 All other requirements of Article 10.1 shall apply.

CHAPTER 11 REPORTING LRFR RATINGS

All Load Rating data must be submitted to FHWA every year. This data is measured in the Metrics, specifically Metric 13. Below are examples of how the data must be coded to ensure proper review for the metric. Below is the typical coding used when reporting to FHWA. Please see Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges and the coding revisions for anything that falls outside of this typical.

11.1 Item 31 Design Load

11.1.1 Shall be coded as the following:

11.1.1.1 Other/Unknown = 0

11.1.1.2 H20 = 4

11.1.1.3 HS20 = 5

11.1.1.4 Pedestrian = 7

11.1.1.5 Railroad = 8

11.1.1.6 HL93 = A

11.2 Item 63 Method to Determine Operating Rating

11.2.1 Shall be coded as the following:

11.2.1.1 Field evaluation and documented engineering judgment = 0

11.2.1.2 Load Factor = 1

11.2.1.3 Allowable Stress = 2

11.2.1.4 No rating analysis performed = 5

11.2.1.4.1 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).

11.2.1.5 Load and Resistance Factor Rating (LRFR) reported by rating factor (RF) = 8

11.3 Item 64 Operating Rating

11.3.1 Shall be coded as the following:

11.3.1.1 If item 63 is coded 0 then use the tonnage

11.3.1.2 If item 63 is coded 1 then use the tonnage

11.3.1.3 If item 63 is coded 5 then use zero

11.3.1.4 If item 63 is coded 8 then use the rating factor

11.3.1.5 If the structure is buried where the live loads are negligible then use 999

11.4 Item 65 Method to Determine Inventory Rating

11.4.1 Shall be coded as the following:

11.4.1.1 Field evaluation and documented engineering judgment = 0

11.4.1.2 Load Factor = 1

11.4.1.3 Allowable Stress = 2

11.4.1.4 No rating analysis performed = 5

11.4.1.4.1 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).

11.4.1.5 Load and Resistance Factor Rating (LRFR) reported by rating factor (RF) = 8

11.5 Item 66 Inventory Rating

11.5.1 Shall be coded as the following:

11.5.1.1 If item 65 is coded 0 then use the tonnage

11.5.1.1.1 If the tonnage is greater than 100 then code as 99.9

11.5.1.2 If item 65 is coded 1 then use the tonnage

11.5.1.2.1 If the tonnage is greater than 100 then code as 99.9

11.5.1.3 If item 65 is coded 5 then use zero

11.5.1.4 If item 65 is coded 8 then use the rating

11.5.1.5 If the structure is buried where the live loads are negligible then use 99.9

11.6 Connecticut Specific Coding

11.6.1 Evaluation Code shall be coded as the following:

11.6.1.1 Evaluated = E

11.6.1.1.1 This shall be used for a buried structure that has enough fill to prevent significant live load from reaching the structure and where the Capacity over Demand ratio is performed to ensure the structure can support the fill over the structure. This shall also be used for masonry structures.

11.6.1.2 Load & Resistance Factor Rating = F

11.6.1.2.1 This shall be used when a load rating was performed using LRFR

11.6.1.3 Judgment Rating = J

11.6.1.3.1 This shall be used on structures when a rating is performed that has no plans and cannot be measured. Generally this should only apply to concrete structures.

11.6.1.4 Load Factor Rating = L

11.6.1.4.1 This shall be used when a load rating was performed using LFR

11.6.1.5 Evaluation Required = R

11.6.1.5.1 This shall be used when a structure requires a load rating to be performed.

11.6.2 Year of Evaluation 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 SUBMISSION PACKAGE

This section describes how the submission package shall be submitted to the Load Rating Section. This package shall be in a digital format. The load rating shall be stamped by a Professional Engineer registered in the State of Connecticut. For load ratings developed for Design Projects please submit the files in ProjectWise following the procedures in the Digital Project Development Manual and an email sent to DOT.BridgeRating@CT.gov notifying the Load Rating Section that the load rating is complete. For load ratings developed outside of a Design Project they should be submitted to DOT.BridgeRating@CT.gov to the Load Rating Section. Sample reports are located on the CTDOT Load Rating Website. The subject line of the e-mails notifying the Load Rating Section that a report is ready for review should follow the following format: Bridge Number Project Number Review Submission Number (e.g. 00001 0123-0123 Review Submission 1).

The structure shall be logged and follow the same naming convention as documented in the most current inspection report. All working files and report documents submitted shall reference and label the structure's components as such. For new structures the bridge shall be logged as specified in the CTDOT Bridge Inspection Manual, Chapter 06, General, Bridge Component Labeling Systems For Inspection Reporting

12.1 Load Rating File

The load rating engineer 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. The major categories listed below must be linked by digital bookmarks within the pdf file for ease of reference. Additional digital bookmarks may be created at the discretion of the Load Rating Engineer.

12.1.1 Report Cover Sheet

12.1.2 Load Rating Summary Sheets

12.1.2.1 This will include all of the critical member information for all of the load cases that is required.

12.1.2.1.1 The member length is the centerline to centerline of bearing for the span for the controlling member.

12.1.2.1.2 The controlling location is where the member experiences the failure mechanism. This will be represented as a decimal percentage of the total length (e.g. 0.5L is at mid-span).

12.1.2.1.3 The controlling mechanism is the governing failure mechanism (for example shear, flexure, etc.) and associated Limit State for the critical location.

12.1.2.2 References

12.1.2.2.1 Include all references (e.g. AASHTO, AISC, ASTM, etc.) including version and most recent interims used in the load rating analysis. References must include inspection report pages used and Bridge plan sheets that assisted in the analysis.

12.1.2.3 Calculation Tools

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

12.1.3 Rating Factors Less than 1.0

12.1.3.1 Include a tabularized output including all rating factors that do not achieve a rating greater than 1.0, and separate the ratings in two tables; (1) AASHTO & CT Legal, and (2) CT

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

12.1.3.1.1 Each table shall include the following columns in the order of: Failure Mechanism, Limit State, Span, Member, Location on Member (Percent), Member Length (feet), Rating Factor, Rating Tons, then Vehicle.

12.1.3.1.2 Each table shall be sorted in the following order: Failure Mechanism, Limit State, Span, Member, Location on Member (Percent), Member Length (feet), Rating Factor, then Vehicle.

12.1.3.1.3 These tables shall only include all Strength, Service I, and Service II ratings.

12.1.3.1.4 The tabularized output should follow a clear and organized format where repair crews can utilize the data for field repairs without manipulation.

12.1.4 Methodology of the Load Rating

12.1.4.1 Analysis

12.1.4.1.1 Include all reasoning behind modeling decisions including but not limited to;

12.1.4.1.1.1 Analysis type

12.1.4.1.1.1.1 If AASHTOWare Bridge Rating software was used and the bridge model was affected by an issued described via JIRA ticket, the following is required:

12.1.4.1.1.1.1.1 JIRA ticket number

12.1.4.1.1.1.1.2 A brief statement of the problem and how the model was affected

12.1.4.1.1.1.1.3 The workaround procedure

12.1.4.1.1.2 Choice of elements used to model components

12.1.4.1.1.3 Utilization of modeling links

12.1.4.1.1.4 Support properties/stiffness

12.1.4.1.1.5 Dummy elements

12.1.4.1.1.6 Construction stages

12.1.4.1.1.7 Vehicle load cases

12.1.4.1.1.7.1 Explain how the trucks were placed on the structure.

12.1.4.1.2 Include an overview on the generation and application of dead loads and live loads including software settings used to produce loads, manual calculations to alter loads, or any other steps taken.

12.1.4.2 Assumptions/Comments

12.1.4.2.1 Include all assumptions that were required to complete the load rating

12.1.4.2.2 Any assumptions that may affect the load rating results are to be included along with rationale and references that led the rating engineer to these assumptions

12.1.4.2.3 Include all comments about the structure in regards to the load rating

12.1.4.2.4 Anything not explicitly stated in the assumptions or calculations that the rating engineer deems appropriate.

12.1.4.3 Primary Members

12.1.4.3.1 Define all of the primary members of the structure. This will include cross frames and diaphragms for curved and high skew structures as specified in Article 1.5.2.9. Explain how the Primary Members are rated.

12.1.5 Calculations

12.1.5.1 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, LLDF's, section losses, beam end calculations, etc.

12.1.5.2 When excel sheets are utilized, sample calculations working through the entire excel workbooks functionality in an easily followed and fully referenced format shall be submitted as a proof of the spreadsheets equations accuracy. An easily followed format includes hand-calculations or MathCAD files without programing other than simple Boolean programing functions.

12.1.5.2.1 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.

12.1.6 Schematics

12.1.6.1 Produced by the analysis program if program capabilities exist

12.1.6.2 Framing plan for the entire structure

12.1.6.3 Cross-section view of all members

12.1.6.3.1 If views are typical and the cross-section view are the same the schematics may be consolidated into typical views

12.1.6.3.2 When the Cross-Section changes, a new cross-section needs to be included (e.g., prestressed members with harped strands should have a beam end cross-section and a mid-span cross-section).

12.1.6.3.3 Show all deterioration that is on the member

12.1.6.4 Elevation views of all members

12.1.6.4.1 If views are typical and the elevations view are the same the schematics may be consolidated into typical views

12.1.6.4.2 Show all deterioration that is on the member

12.1.7 Program Input Data

12.1.8 Appendix

12.1.8.1 Includes copies of pages from a reputable manual (MSC, PCI, etc.) to show beam shapes and member properties (as needed).

12.1.8.1.1 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.

12.1.8.2 Includes copies of pages that support any assumptions.

12.1.8.2.1 For example, bridge rail weight/foot, weight of steel grating per area, etc.

12.1.8.3 Includes copies of design calculation pages (if used).

12.1.8.4 Includes copies of all relevant sections of the inspection report(s) used for the analysis such as the BRI-19 to show ADTT, the BRI-18 to show curb reveal, Field Notes to show section losses, etc. Each inspection report sheet included should be rotated to its appropriate orientation.

12.1.8.5 Includes copies of all plan sheets used in analysis.

12.2 Load Rating Reference File

12.2.1 Raw files

12.2.1.1 Examples of raw files

12.2.1.1.1 Input file from the program being used. This shall include the model of the structure.

12.2.1.1.2 Excel files

12.2.1.1.3 MathCAD files

12.2.1.1.4 CAD files

12.2.1.1.5 Other files used in the analysis

12.2.1.1.6 See Chapter 13, Approved Software, for additional program specific requirements.

12.3 Naming of Submission Files

12.3.1 Load Rating File

12.3.1.1 Shall follow this format: Bridge Number_YYYY-MM-DD_Description of the file.pdf

12.3.1.1.1 Description of the file will be as follows

12.3.1.1.1.1 Existing Load Rating = LR

12.3.1.1.1.2 Research Study Report Load Rating = RSR_LR

12.3.1.1.1.3 Final Design Load Rating = FDP_LR

12.3.1.2 An example is shown in CT-LRM Figure 12.1.

12.3.2 Load Rating Reference File

12.3.2.1 Parent File

12.3.2.1.1 This is the zip file

12.3.2.1.2 This file should include all raw files.

12.3.2.1.3 Shall follow this format: Bridge Number_YYYY-MM-DD_Description of the file.zip

12.3.2.1.3.1 Description of the file will be as follows

12.3.2.1.3.1.1 Existing Load Rating = LR_References

12.3.2.1.3.1.2 Research Study Report Load Rating = RSR_LR_References

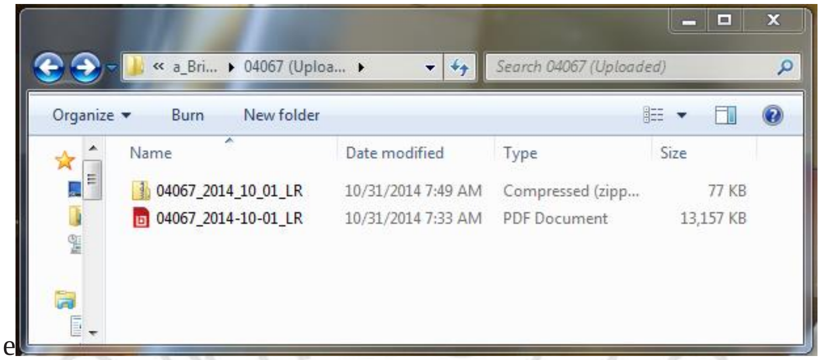
12.3.2.1.3.1.3 Final Design Load Rating = FDP_LR_ References

12.3.2.2 Files contained in Parent File

12.3.2.2.1 Shall follow this format: Bridge Number_YYYY-MM-DD_Description of the file

12.3.2.2.1.1 The description of the file should be clear enough for the Load Rating Section to know what the file contains. An example is shown in **Figure 12.2**.

12.3.2.3 An example is shown in **Figure 12.1**.



e

Figure 12.1

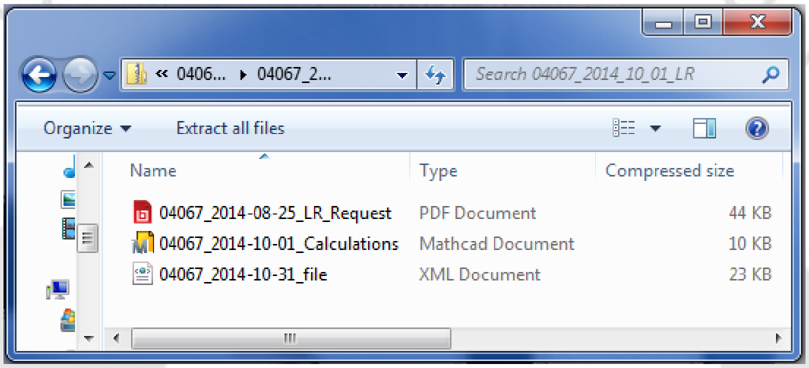


Figure 12.2

12.4 Interpretation of Rating Results and Low Ratings

12.4.1 In cases where load rating results are below the required 1.00 rating factor, the load rating engineer shall review the ratings to ensure that overly conservative assumptions have not led to overly conservative rating results prior to submission to The Department.

CHAPTER 13 APPROVED SOFTWARE

13.1 AASHTOWare Bridge Rating

13.1.1 AASHTOWare is the Department's software of choice. Other software must be approved by the Load Rating Section prior to the start of the load rating. The Rater is responsible for reviewing all applicable JIRA tickets to ensure the reported issues do not affect the AASHTOWare bridge model. If a JIRA ticket is found to affect the AASHTOWare bridge model and a workaround for this issue is available, refer to Chapter 12.1.4 for reporting. AASHTOWare shall be used for all CTDOT load ratings with the following exceptions.

13.1.1.1 Timber superstructures and decks

13.1.1.2 Arches (steel, concrete, masonry)

13.1.1.3 Rigid Frames (other than box culverts)

13.1.1.4 If given prior approval from the CTDOT Load Rating Section.

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

13.1.2 General Requirements

13.1.2.1 A BWS report shall be generated for the Submission Package for review.

13.1.2.1.1 CTDOT's BWS report templates can be found on the CTDOT Load Rating Website

13.1.2.1.2 In the event that a CTDOT BWS template does not fit the structure type the Rater shall create their own Template following the configuration of available CTDOT BWS templates

13.1.2.2 Each bridge structure number shall be contained in a single input file. Therefore, the Submission 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.

13.1.2.3 The Superstructure Definitions naming convention shall be as follows: YYYY_Span ##, where YYYY is the 4 digit year the load rating was performed for and Span ## is the span currently being analyzed. For example, Bridge 00001, Span 2 load rated in 2016 would be 2016_Span 02.

13.1.2.3.1 If the bridge being load rated contains two superstructures, each carrying a separate direction of traffic the Superstructure Definitions naming convention shall be as follows: YYYY_Span ##_XX, where YYYY is the 4 digit year the load rating was performed for, Span ## is the span currently being analyzed, and XX is the applicable travelway direction. For example, Bridge 00001, Northbound, Span 2 load rated in 2016 would be 2016_Span 02_NB.

13.1.2.4 The Bridge Alternatives naming convention shall be the 4 digit year the load rating was performed.

13.1.2.4.1 The Superstructures naming convention shall be as follows: Span ##_XX, where Span ## is the span currently being analyzed and XX is the travelway direction, if applicable.

13.1.2.5 When creating a member alterative, use the "Schedule based" girder property input method when able. The "Cross-section based" method shall only be used when modeling built-up members or with prior approval from the Load Rating Section.

13.1.2.5.1 Member alternative naming shall be unique and descriptive to each member. Naming a girder Copy of X is not acceptable.

13.1.2.6 Place each diaphragm at its appropriate location with its calculated weight. The diaphragms must be assigned to a definition when performing a finite element analysis.

13.1.2.6.1 At a minimum, an additional 10% shall be added to the total weight of each diaphragm to account for miscellaneous hardware (e.g., bolts, welds, etc.). Ensure all calculations are submitted in accordance with Chapter 12 requirements.

13.1.2.6.2 Diaphragm connection plate weights shall be calculated and included in the diaphragm weights. Note that the connection plate weights are not accounted for in the additional 10% applied for miscellaneous hardware.

13.1.2.7 Use the "Default Load Case Descriptions" when able.

13.1.2.7.1 If additional load cases are used, ensure each case is renamed and a descriptive title is used to identify the load case (e.g., copy DC1 and re-name it 'DC1 stiffener weight' if adding the weight of the stiffeners to the girder).

13.1.2.8 It is often easier to add the weight of a bridge rail/fence to the parapet rather than create a railing in the "Appurtenances" folder. Either method is acceptable.

13.1.2.9 If utilities are present, place each utility load at the appropriate location within the "Member Loads" section with the calculated weight.

13.1.2.9.1 All utility weight calculations shall include an additional 10% to account for miscellaneous hardware (e.g., bolts, welds, etc.). Ensure all calculations are submitted in accordance with the Chapter 12 requirements.

13.1.2.10 In the "Lane Position" tab of the "Structure Typical Section" folder, the "Compute" button will not place the travel lane on safety walks/sidewalks. If the curb is mountable, i.e. the curb extends less than 6" above the top of the wearing surface, manually extend the travel lane to cover the sidewalk width. Note that when this is done, the wearing surface is also superimposed over the sidewalk along with the travel way. This produces conservative results and does not need to be modified unless it is causing low rating factors, in which case the Load Rating Engineer must apply member loads to counteract the additional load applied to the girders from the extended wearing surface.

13.1.2.11 AASHTOWare Bridge Rating cannot model curved decks on straight members. The following method is acceptable to approximate the loading of a curved deck on straight members. Failure to perform all of the steps outlined below will result in an unreasonable and inaccurate model.

13.1.2.11.1 In the structure typical section, enter the maximum overhang for both left and right overhangs. This ensures the maximum live load distribution factors are calculated in the program. If this produces overly conservative load rating results due to deterioration at certain locations or other factors, the live load distribution factors must be calculated independently for ranges along the girder.

13.1.2.11.2 Modify the 'Structure Typical Section' by adding 0.001 to the 'Distance from left edge of deck to superstructure definition reference line' 'End'. This enables the user to enter different Start and End values for the effective flange width in the member 'Deck Profile' section.

13.1.2.11.3 Calculate the dead load overage caused by using the maximum overhang in the model between the beam ends and mid-span. Convert this load into a gradient loading that will be entered in the 'Member Loads' 'Distributed' section as an uplift gradient loading from member end to mid-span and then another load from mid-span to member end. Using an approximate linear varying loading is acceptable as long as the approximate loading to be removed does not exceed the actual loading that should be removed.

13.1.2.11.4 Compute the effective flange width between the member ends and the mid-span of the beam.

In 'Deck Profile" 'Deck Concrete', the deck properties can be entered as a range. The range from the start of the member to the mid-span will have a linearly variable approximated effective flange width and another range from the mid-span to the member end will have another linearly variable effective flange width. This linearly variable effective flange width shall not exceed the actual effective flange width at any location along the beam.

13.1.2.12 For each member alternative, ensure the correct condition and system factors are selected in the "Factors" tab. "Field measured section properties" should be selected if the deterioration analyzed if based off of measurements depicted in the most recent inspection report.

13.1.2.13 The load rating References folder shall include the LRFR Report XML located in the 'My Documents/AASHTOWare/BrDR[XX]/Reports/LRFRReport.XML' , where [XX] is replaced by the programs version.

13.1.2.14 The load rating References folder shall include the analysis files stored in the users 'My Documents' folder. The bridge folder containing the entire analysis files is located in 'My Documents/AASHTOWare/BrDR[XX]', where [XX] is replaced by the programs version.

13.1.3 Concrete specific requirements

13.1.3.1 In the "Control Options" tab of each member alternative, the following options in the LRFR column should be selected (**Figure 13.1** shows a simple span concrete member. **Error! Reference source not found.** shows a continuous span concrete member):

13.1.3.1.1 Points of Interest: Select all options

13.1.3.1.2 Shear Computation Method: General Procedure

13.1.3.1.3 Loss & Stress Calculations: Use gross section properties

13.1.3.1.4 Multi-span analysis: Continuous

13.1.3.1.5 Consider legal load tensile concrete stress

13.1.3.1.6 Consider permit load tensile steel stress

13.1.3.1.7 Ignore long. reinf. in rating: Select this option for simple spans only.

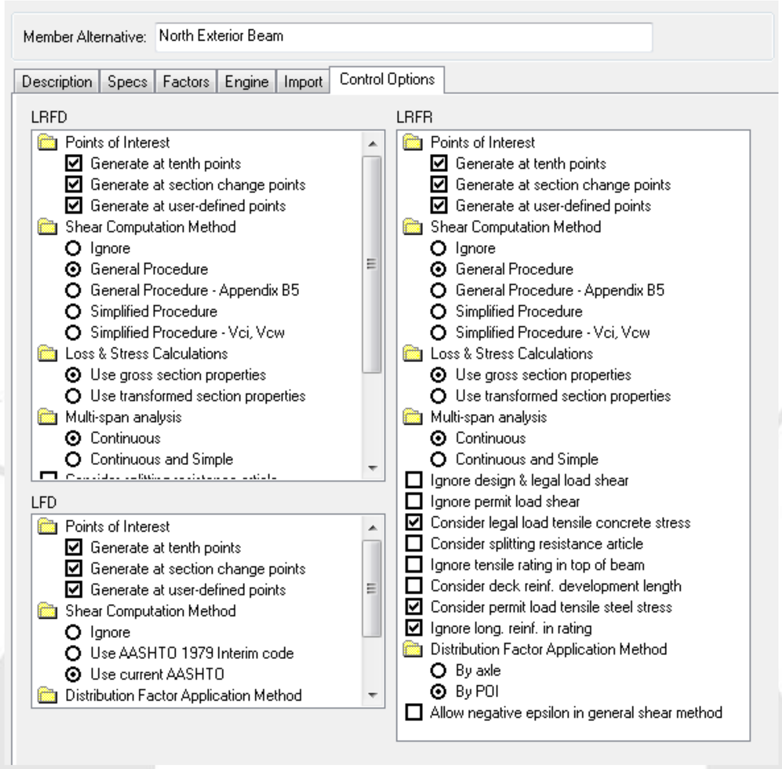


Figure 13.1 - Simple Span Concrete Member Control Options

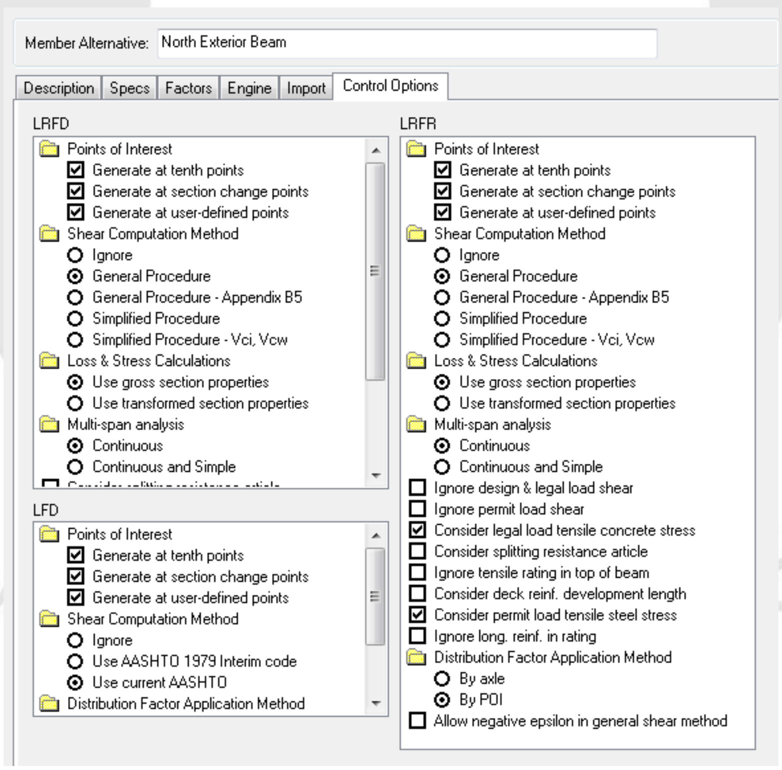


Figure 13.2 – Continuous Span Concrete Member Control Options

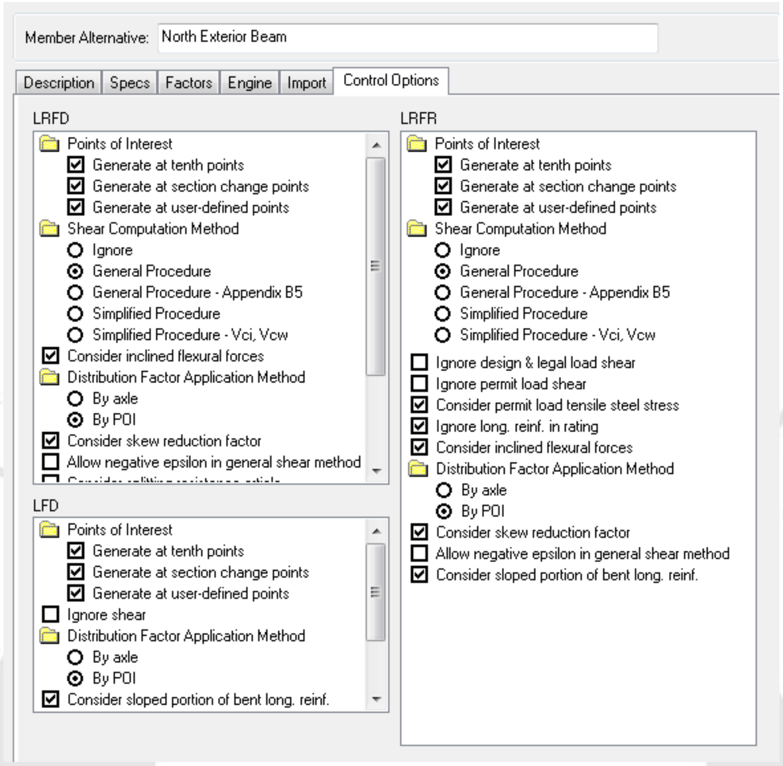


Figure 13.3 – Reinforced Concrete Slab Control Options

13.1.3.1.8 When the structure plans only provide the center of gravity and the jacking force, the Load Rater must use the PS&CGS method in AASHTOWare BrDR.

When using this method, the program auto-calculates the area of the prestressing strands by dividing the jacking force by the product of the Prestressed Strand Tensile Strength and the 'Stress Limitations for Prestressing Tendons' factor f_{pbt} (AASHTO LRFD Table 5.9.3-1). The use of this table is for design purposes and does not correctly calculate the total area of prestressing strands if the tendons are not stressed to the maximum limits in AASHTO LRFD Table 5.9.3-1. To produce the correct area, the jacking stress ratio entered into the 'Prestress Properties' dialog must be modified per equation 13-1 below:

$$Jacking\ Stress\ Ratio = \frac{(Jacking\ Force\ per\ Strand)*(Number\ of\ Strands)}{(Total\ Area\ of\ Prestressing)*(Prestressed\ Strand\ Tensile\ Strength)}$$

Equation 13-1

13.1.4 Steel specific requirements

13.1.4.1 Stiffener self-weight must be manually applied.

13.1.4.2 The cover plate start and end locations shall be lessened by 1.5 x (Cover Plate Width) to account for the cover plate transition length as required by Article 6.6. In order to evaluate fatigue at the actual cover plate end, the user will need to create a "Fatigue Point of Interest" at the actual cover plate end.

13.1.4.3 AASHTOWare's gusset plate analysis is limited to simple plate configurations. For truss nodes with unique geometry or multiple plates, additional hand calculations may be required, using the concurrent forces given in the AASHTOWare output.

13.1.4.4 The LRFR "Control Options" shall be selected as shown in Figure 13-3. Note that AASHTOWare will perform a check to determine if the selected options are applicable. For any member that does not meet the requirements set forth by AASHTO in order to take advantage of any optional checks selected, AASHTOWare will automatically disregard the selected option.

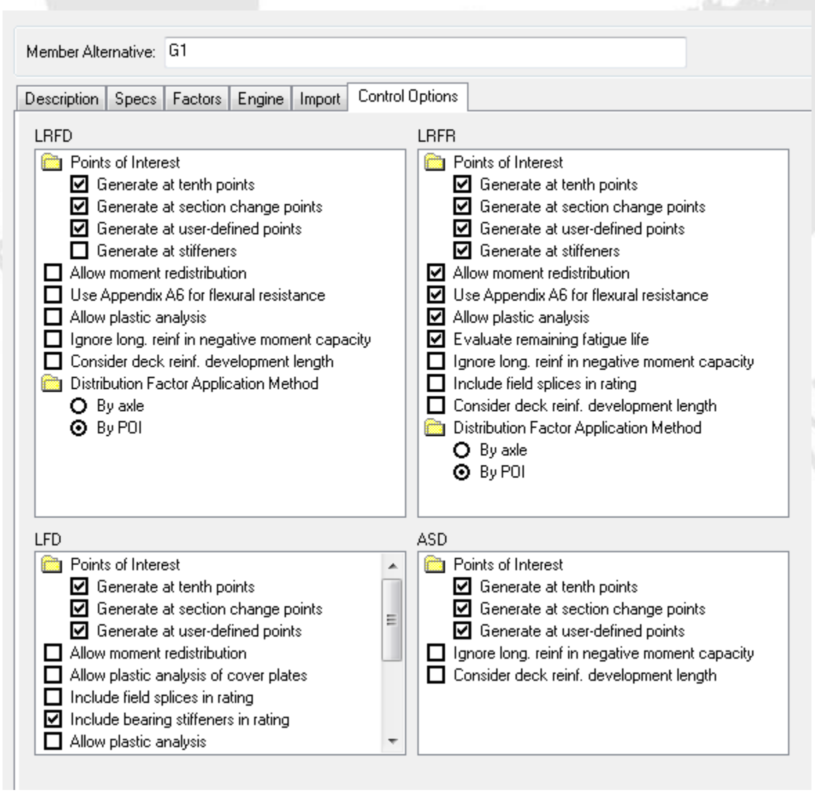


Figure 13.4 – Steel Control Options

13.2 Bentley Software Packages

13.3 CANDE

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

13.3.1.2 Limitations

13.3.1.2.1 A Level 3 analysis is required in order to accurately place the wheel loads of CTDOT's required load conditions

13.3.1.2.2 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.

13.3.1.2.3 A minimum of four (4) 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:

13.3.1.2.3.1 The culvert/buried structure material

13.3.1.2.3.2 The soil at the sides of the buried structure

13.3.1.2.3.3 The soil at the top of the buried structure

13.3.1.2.3.4 Live loads applied as boundaries.

13.3.1.3 Applying the wheel load incrementally leads to fewer convergence issues. Four wheel load increments are suggested.

13.3.1.4 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.

13.3.1.5 Types of bridges used for

13.3.1.5.1 Pipe culverts, lined pipes, and arch structures.

13.4 ETCulvert

13.5 Staad.Pro

13.6 Larsa 4D

13.6.1 A folder of the entire analysis generated by the program should be included in the References folder.

13.7 Midas

13.7.1 A folder of the entire analysis generated by the program should be included in the References folder.

13.7.2 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

13.8.1.1 Buried Structures

13.8.1.1.1 Metal Structures (coming soon)

13.8.1.1.1.1 Limitations

13.8.1.1.1.1.1 Currently only circular and pipe arch structures are supported.

13.8.1.1.1.1.2 Analyzing perforated areas is not supported. Properties cannot be changed throughout the cross-section; an area with section loss will evaluate the entire cross-section with the section loss properties.

13.8.1.1.1.1.3 The program does not account for increased stress in locations adjacent to perforations or section loss.

13.8.1.1.2 Plastic Structures (coming soon)

13.8.1.1.3 Concrete Structures (coming soon)

13.8.1.2 Beam End Analysis

13.8.1.2.1 Limitations

13.8.1.2.1.1 Deterioration variation at different heights is not reflected in the analysis; currently either a worst case or average case is analyzed.

13.8.1.2.1.2 Partial height connection plates, partial height stiffeners and full height connection plate or stiffeners with full width deterioration cannot be used to increase the capacity for web yielding as the web without the plate is still susceptible to yielding. Webs with partial height stiffeners/plates or stiffeners/plates with full width deterioration need not be checked for web crippling if the stiffener or plate extends for a minimum of three quarters the depth of the web per guidance given in the AISC Engineering Journal, Volume 52, No. 4 article titled *Crippling of Webs with Partial-Depth Stiffeners under Patch Loading*.

CHAPTER 14 QUALITY CONTROL/QUALITY ASSURANCE PROCEDURE

14.1 Quality Assurance

14.1.1 Who is responsible for what?

14.1.1.1 Rater Responsibility

14.1.1.1.1 The Rater is responsible for all of the structural analysis performed, assumptions made about the structure, assumptions made about the calculations, and the Load Rating Report submitted.

14.1.1.1.2 Any corrections not made to a reviewed report must be accompanied by an explanation of why the change was not made.

14.1.1.2 Reviewer Responsibility

14.1.1.2.1 The Reviewer is responsible for ensuring the Rater performed the load rating correctly and used sound engineering judgment on all of the assumptions.

14.1.1.2.2 The Reviewer shall review all the data input within the modeling software to confirm the model does not contain extraneous information.

14.1.1.2.3 The Reviewer shall verify the Load Rating Report follows the guidelines in Chapter 12.

14.1.1.2.4 The Reviewer is responsible for signing the Quality Assurance statement located on the report coversheet.

14.2 Quality Control

14.2.1 Who is responsible?

14.2.1.1 The Load Rating Section is responsible for performing checks of submitted and stamped load rating reports.

14.2.2 Review Period

14.2.2.1 The Load Rating Section requires at least 20 business days per review submittal to schedule and complete a review of a load rating from a design project. This review requires the stamped Load Rating Report and all supporting material.

14.2.2.1.1 Major structures and complex load rating reports may require additional time depending on scheduling and the quality of the report submitted.

14.2.3 Corrective Action

14.2.3.1 The Department gathers metrics on all load ratings submitted. If there are continual concerns over the correctness, accuracy or other adherence to this manual or any of its referenced documents, the Department will take corrective action which may include but is not limited to:

14.2.3.1.1 Education

14.2.3.1.2 Submittal of QA/QC documentation for each submitted load rating

14.2.3.1.3 Load Rating checklists for each load rating with manager sign off

14.2.3.1.4 Non-acceptance of additional load ratings until the areas of concern are corrected

CHAPTER 15 BIBLIOGRAPHY

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APPENDIX A. RATING EXAMPLES