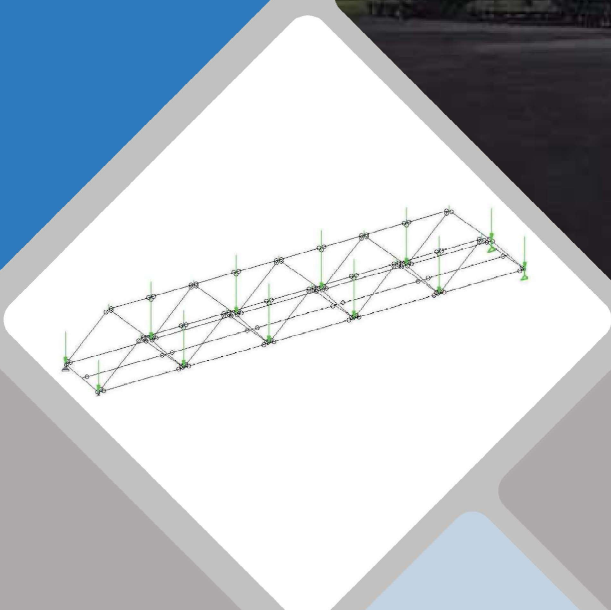
DELAWARE DEPARTMENT OF TRANSPORTATION

BRIDGE LOAD RATING MANUAL

2023 EDITION

DelDOT

BRIDGE SECTION



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DelDOT

Bridge Load Rating Manual

2023

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Bridge Management Section

BRIDGE LOAD RATING MANUAL
2023 Edition

Adopted as policy for all DelDOT Bridge Load Rating Activities as of October 1, 2023

Recommended By:

Bridge Management Engineer

Recommended By:

Chief of Bridges & Structures

Approved By:

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Approved For Use on All Federal Aid Projects By:

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Preface

Every effort has been made to develop a complete and comprehensive manual which covers the most common situations faced by the DelDOT Bridge Load Rating Program. However, this Manual should be used in conjunction with corresponding design codes and proper bridge load rating training along with the exercise of good engineering judgement by load raters and Professional Engineers, especially in cases involving public safety.

Techniques, standards, policies, and technology for bridge load rating constantly evolve. To remain current, this document will be updated over time to reflect Federal, Delaware State and Local Standards and the industry’s changing practices. Updates will be distributed by the Bridge Management Engineer when appropriate.

Comments and suggestions for improvement of this Manual should be forwarded to the Bridge Management Engineer.

This manual is effective as of October 1, 2023.

Terms & Abbreviations

AASHTO – American Association of State Highway and Transportation Officials

ASTM – American Society of Testing and Materials

BDM – *Bridge Design Manual*, DelDOT

BD PM – Bridge Design Project Manager

BDS – *AASHTO LRFD Bridge Design Specifications*

BEIM – *Bridge Element Inspection Manual*, DelDOT

BIE – *Bridge Inspection Engineer*

BIM – *Bridge Inspection Manual*, DelDOT

Bridge (Federal) – Structures, including supports, erected over a depression or an obstruction such as water, a highway or a railway with tracks or passageways for carrying traffic or other moving loads on a public roadway and with openings measured along the center of the roadway of more than 20 feet between undercopings of abutments, spring lines of arches, or the extreme ends of openings for multiple boxes. The term "bridge" shall also include multiple pipe structures where the clear distance between pipe openings is less than half of the smaller pipe diameter(s), and the combined structure exceeds 20 feet in total span length.

Bridge (Municipal & Local Agency) – Any structure meeting the Federal definition of a bridge and that is owned by a Municipality or other Local Agency.

Bridge (Private) – Any structure not owned by the State or Municipality carrying vehicular or pedestrian traffic on or over a State maintained or public roadway regardless of length of bridge.

Bridge (State) – All structures meeting the Federal definition of a bridge, all State-owned bridge and culvert structures having an opening of greater than 20 square feet, and a minimum vertical opening of 48 inches, State-maintained pedestrian structures over roadways, and DelDOT owned pedestrian bridges over waterways.

BME (Bridge Management Engineer)– The Bridge Management Engineer oversees the Bridge Inspection, Bridge Load Rating, Bridge Management, and Bridge Maintenance Programs, and is responsible for load posting bridges.

BM LR – Bridge Management Load Rater

BMS (Bridge Management Section) – The Bridge Management Section is responsible for activities involving the Bridge Inspection, Bridge Load Rating, Bridge Management, and Bridge Maintenance Programs.

BrM – AASHTOWare Bridge Management software

DelDOT – Delaware Department of Transportation

DE MUTCD – Delaware Manual on Uniform Traffic Control Devices

DNREC – Delaware Department of Natural Resources and Environmental Control

DRBA – Delaware River and Bay Authority

FEM – Finite Element Modeling

FHWA – Federal Highway Administration

GVW – Gross Vehicle Weight

LR (Load Rater) – The Load Rater is the individual, meeting the qualifications described herein, assigned to perform the load rating of a specific bridge.

LRE (Load Rating Engineer) – The Load Rating Engineer is the individual charged with the overall responsibility for load rating bridges in Delaware for compliance with the NBIS. This includes leading the QC process, assigning load ratings, providing training as needed, and developing load rating procedures and protocols.

LRR (Load Rating Reviewer) – The Load Rating Reviewer is the individual, meeting the qualifications described herein, assigned to check the load rating of a specific bridge.

LRFR - Load and Resistance Factor Rating

MBE – *Manual for Bridge Evaluation*, AASHTO

MCFT – Modified Compression Field Theory

MPF – Multiple Presence Factor

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

NBI (National Bridge Inventory) – The aggregation of structure inventory and appraisal data collected to fulfill the requirements of the National Bridge Inspection Standards. DelDOT shall prepare and maintain an inventory of all bridges subject to the NBIS.

NBI Coding Guide – *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*, FHWA

OSOW – Oversize / Overweight

OSOW Manual – Oversize / Overweight Hauling Permit Policy and Procedures Manual

PE – Professional Engineer

PM (Project Manager) – The individual (DelDOT or Consultant) responsible for managing the bridge project.

QA – Quality Assurance

QC – Quality Control

SHV – Specialized Hauling Vehicle

SI&A – Structure Inventory & Appraisal

USACOE – United States Army Corps of Engineers

Section 1 – Bridge Load Ratings

1.1 Introduction

This document provides guidance on the development of bridge load ratings. Additional information on bridge inspection procedures and load ratings can be found in the current DelDOT BIM.

1.2 Application

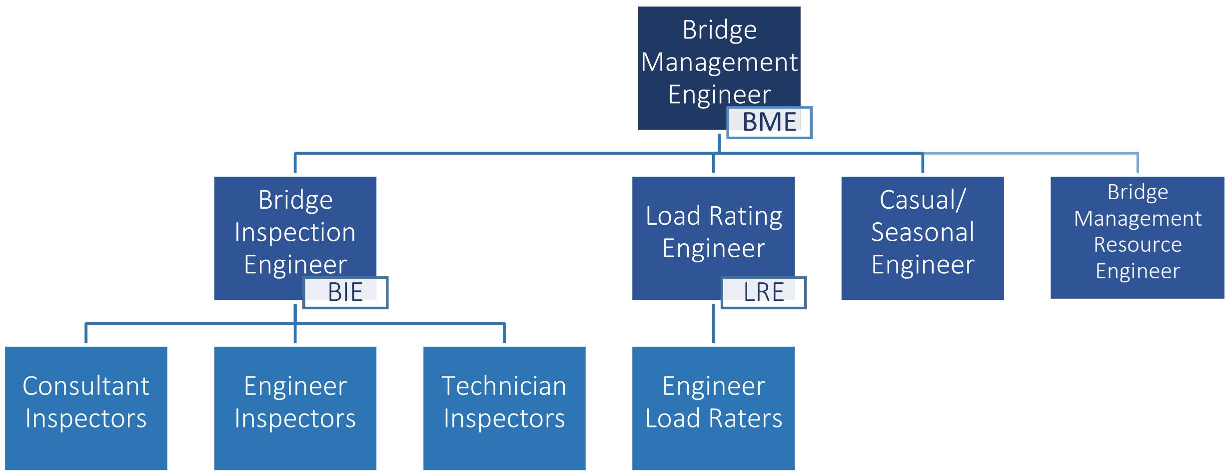
The National Bridge Inspection Standards (NBIS) requires each state transportation department to inspect, prepare reports and determine load ratings for structures defined as bridges on all public roads. The NBIS is contained in Title 23 of the Code of Federal Regulations (CFR) Part 650, Subpart C.

Only bridges that meet the Federal definition are included in the National Bridge Inventory (NBI). In addition to the NBI, DelDOT maintains an inventory of State, Municipal, Other Local Agency, and Privately-owned bridges.

DelDOT's policy is to perform load ratings on all DelDOT-owned vehicular structures meeting either the Federal or State definition of a bridge. However, load ratings are only required for NBI bridges for non-DelDOT bridge owners. This Manual covers the general requirements and procedures for bridge load ratings. For structural types, materials, and analysis methods not discussed in this Manual, contact the BMS for further guidance.

1.3 Organization Chart

Below is DelDOT's Bridge Management Section organization chart.



1.4 Load Rating Specifications

In general, DelDOT adopts the load rating procedures in the current MBE. LR should refer to that publication for any items not specifically covered by this Manual. If there are differences between this Manual and the MBE, this Manual governs.

1.5 Load Rating Process

The load rating review and acceptance process shall be in accordance with the process outlined in this section. The load rating will be performed by DelDOT staff or Consultants as outlined below.

There are three primary reasons for performing a load rating:

- Routine load rating program
- Condition-based load rating
- Bridge Design projects

DelDOT BM LR staff are responsible for performing the load rating for bridges within the routine load rating program, bridges with a "Poor" condition rating from a recent bridge inspection, and for in-house bridge design projects in accordance with Section 1.10 of this Manual. The LRE will be responsible for assigning the load ratings to LR staff. Bridge design projects may consist of new bridges, bridge replacements, or bridge rehabilitations. At Quarterly Bridge Meetings, DelDOT staff shall discuss any current and upcoming bridge design projects to identify load rating assignments for BMS staff for scheduling of load rating related activities. The *Annual Load Rating Schedule* spreadsheet will be updated to accommodate any new load rating assignments or updates to existing load rating assignments accordingly.

Consultants are responsible for performing load ratings for bridges within the routine load rating program as assigned through the BMS and bridges they design for bridge design projects. The Bridge Design Project Manager will be responsible for assigning the load ratings to consultants for consultant design projects. Bridge design projects may consist of new bridges, bridge replacements, or bridge rehabilitations. For bridge design rehabilitation projects, Consultants are responsible for completing the load rating based on the final condition of the completed rehab project, and they may be assigned the task by the BD PM to perform a design-level inspection to determine the existing load rating.

Load ratings are performed by the DelDOT or Consultant LR and reviewed by the LRR. For DelDOT staff load ratings, the LRR can be the LRE or BME. If the load rating is performed by the LRE, it should be submitted to the BME for review. For Consultant load ratings, the LRR shall be part of the Consultant's staff. Load ratings shall be performed in accordance with the MBE, the BDS, this Manual, and DelDOT's various load rating documents. Any questions should be directed to the LRE.

1.5.1 Routine and Condition-Based Load Rating Programs

The Load Rating Process outlined below shall be followed by DelDOT and Consultant load rating staff for the routine and condition-based load rating programs.

Step 1: Load ratings will be assigned to DelDOT staff or Consultants by the LRE and identified in the *20XX Load Rating Schedule*. The assigned load rating will be performed by the designated LR.

Step 2: Upon completion of the draft load rating, the LR shall submit a set of load rating documents to the LRE. This set shall include all documentation as described in Section 1.11 of this Manual. The load rating output files are required regardless of the type of software used. Documentation detailing all load rating assumptions and load rating analysis methodology should also be included in the set.

- For DelDOT staff load ratings, LR shall also upload relevant files to the "Ratings_to_be_Reviewed" folder on the network and update the *Annual Load Rating Schedule* spreadsheet to indicate the date the draft load rating was completed.
- For Consultant load ratings, the consultant shall send all relevant load rating files to DelDOT's PM. The DelDOT PM will send the load rating documents to the BMS for review. The LRE shall upload relevant files to the "Ratings_to_be_Reviewed" folder on the network and update the *Annual Load Rating Schedule* spreadsheet to indicate the date the draft load rating was completed.

The LRE or BME shall review the draft load rating and provide comments back to the LR within two weeks of the draft load rating submittal. The load rating comments will be documented in the *QC Load Rating Form* and sent to the LR. The LRE or BME shall update the *Annual Load Rating Schedule* spreadsheet to show the date the review was completed.

Step 3: Upon review by the LRE or BME, the LR shall update the load rating accordingly within two weeks. Once all changes to the load rating have been made, the LR shall submit the updated set of documents to the LRE along with the appropriate forms for one last brief review. The LRE will then notify the BME via e-mail that the load rating is ready to be finalized.

Step 4: The BME will update the BrM database, the *Annual Load Rating Schedule* spreadsheet, the *EF Permit Analysis Master List*, and any additional tracking or data spreadsheets. All load rating files will also be moved from the LR's "Ratings_to_be_Reviewed" folder to the "Finalized_Ratings" folder on the network.

- For DelDOT staff, the BME will print everything out and provide the rating to the LR and LRE for signature.
- For Consultants, the LRE will notify the LR that the documents can be signed and returned electronically. The BME will print the load rating document to place in the corresponding bridge file.

Once the finalized load rating has been signed and returned, the BME will place the file back in the bridge inspection filing cabinet.

Step 5: If the load rating results in a new, modified, or removed load posting, the BME will proceed with the Load Posting Process as outlined in Section 2 of this Manual.

While the BMS strives to adhere to the load rating activity timelines that are discussed above and identified in the BIM for both, Routine and Condition-Based load ratings, failure to meet timeline milestones are not scrutinized when completing Routine load ratings. This flexibility is needed to accommodate surges in load rating activities for Bridge Design Projects, staffing resource limitations, and to meet hauling permit review requirements. Condition-Based load ratings shall strictly adhere to the timeline requirements as identified here and in the BIM.

1.5.2 Bridge Design Projects

The Load Rating Process outlined below shall be followed by DelDOT and Consultant load rating staff for bridge design projects.

Step 1: Load Rating will be assigned to DelDOT staff by the LRE and to consultant staff by the PM.

- For DelDOT staff, draft load ratings shall be performed *after* the Semi-Final Construction Plan set has been received.
- For Consultants draft load ratings shall be performed *prior* to the Semi-Final Construction Plan submission.

Step 2: Upon completion of the draft load rating, the LR shall submit a set of load rating documents to the LRE. This set shall include all documentation as described in Section 1.11 of this Manual. The load rating input and output files are required regardless of the type of software used. Documentation detailing all load rating assumptions and load rating analysis methodology should also be included in the set.

- For DelDOT staff load ratings, LR shall also upload relevant files to the "Ratings_to_be_Reviewed" folder on the network and update the *Annual Load Rating Schedule* spreadsheet to indicate the date the draft load rating was completed.
- For Consultant load ratings, the consultant shall send all relevant load rating files to DelDOT's PM. The DelDOT PM shall send the load rating document to the BMS for review. The LRE shall upload relevant files to the "Ratings_to_be_Reviewed" folder on the network and update the *Annual Load Rating Schedule* spreadsheet to indicate the date the draft

load rating was completed. A summary of the Semi-Final load ratings shall be provided on the Construction Plans using the Load Rating Summary Table as identified in Section 1.11 of this Manual.

The LRE or BME shall review the draft load rating and provide comments back to the LR within the timeframes specified by the BIM. The load rating comments will be documented in the *QC Load Rating Form* and sent to the LR.

Step 3: Upon review by the LRE or BME, the LR shall update the load rating accordingly within the timeframes specified by the BIM. The LRE will also notify the DelDOT Project Engineer and Consultant PM of any load rating issues that need to be corrected or addressed. Once all corrections to the load rating have been made, the LR shall submit the updated set of documents to the LRE along with the appropriate forms for one last brief review. If any structural changes occur between the Semi-Final Construction Plan stage and the Final Construction Plan stage, the designer must notify the LRE of these modifications so the bridge load rating can be re-evaluated. The LRE will then notify the BME via e-mail that the load rating is ready to be finalized.

Step 4: The BME will perform a brief review of the load rating and will update the *Annual Load Rating Schedule* and the *Bridge Design Projects* spreadsheets. The load rating files will also be moved from the “Ratings_to_be_Reviewed” folder to the “Bridge Design Projects” folder on the network.

- For DelDOT staff, the BME will print everything out and provide the rating to the LR and LRE for signature. The BME will also e-mail the LRE to proceed in e-mailing the DelDOT Project Engineer to provide the Load Rating Summary Table as identified in Section 1.11 of this Manual for inclusion with the Final Plan Submission.
- For Consultants, the LRE will notify the LR that the documents can be signed and returned electronically. The Consultant LR or PM will update the Load Rating Summary Table as identified in Section 1.11 of this Manual for inclusion with the Final Plan Submission to accommodate any changes that were made to the draft load rating.

Once the finalized load rating has been signed and returned, the file will be placed back in the bridge inspection filing cabinet.

Step 5: Any structural modification made during construction shall be communicated to the LRE so the bridge load rating can be re-evaluated. The corresponding approved shop or as-built drawings should be provided to the LRE so the load rating can be re-evaluated for any modifications to the structure.

While the BMS strives to adhere to the load rating activity timelines for that of Condition-Based load ratings when completing load ratings for Bridge Design projects, failure to meet interim milestones are not scrutinized. Ultimately, the only mandatory time constraint is that the load rating must be finalized, and the Load rating Summary Table distributed to the appropriate DelDOT Project Engineer or Manager prior to the Final Plan Submission. For Bridge Design projects that include the design of an ASTM C1577 concrete box culvert, the load rating will not be started until the shop drawings are submitted. Because the load rating process does not start until after the project has been awarded and is in construction, the Load Rating Summary Table is *not* included with the Final Plan Submission.

Step 6: Once the project has been completed, the following activities will occur:

- Bridge will be inventoried in accordance with the BIM.
- Load rating data is updated in the BrM by the BME.
- The BME will move the load ratings file from the "Bridge Design Projects" folder to the "Finalized_Ratings" folder on the network. A copy of the load rating document will be placed in the inspection file.

If the load rating results in a new, modified, or removed load posting, the BME will proceed with the Load Posting Process as outlined in Section 2 of this Manual.

1.6 Responsibility

Most bridges in Delaware are owned and operated by DelDOT. In Delaware, bridges that are not owned and operated by DelDOT are owned by cities, railroad companies, DRBA, DNREC, USACOE, or other private owners.

DelDOT policy is to perform load ratings for municipal and all state-owned bridges that meet the Federal definition of a bridge. All other Owners are required to load rate vehicular structures that are included in the NBI in accordance with the NBIS and MBE. Owners are responsible for sending their bridge inspection and load rating results to the BME for inclusion in the NBI.

Title 17, Chapter 5, Section 510 of the Delaware Code allows DelDOT to conduct investigations of the load carrying capacity of certain bridges, regardless of ownership or jurisdiction if DelDOT has concerns for the safety of a bridge.

1.7 Quality Control Procedures

Maintaining a high degree of accuracy and consistency in the load rating program is important. The QC procedures described herein are intended to assist in ensuring this level of quality.

1.7.1 Quality Control Roles and Responsibilities

All QC activities fall under the responsibility of the LRE, unless the BME is reviewing a load rating completed by the LRE. All personnel involved in the load rating process shall meet the requirements of this Manual.

1.7.2 Load Rating Engineer Qualifications

The LRE shall be a Delaware Licensed PE. In addition, the LRE shall have experience in structural analysis and load rating procedures of all common bridge structure types.

1.7.3 Load Rater Qualifications

All LR's shall possess a bachelor's degree or higher in Civil Engineering. LR's shall also have general knowledge of structural analysis methods and/or structural design.

1.7.4 Load Rating Reviewer Qualifications

The LRR shall be a Delaware Licensed PE. In addition, the LRR shall have experience in structural analysis and load rating procedures for all common bridge structure types. The Consultant is required to submit LRR qualifications to the LRE along with the load rating documents as part of the draft submission.

1.7.5 Review and Validation of Load Rating Reports

The LR shall perform a thorough review of the data and results of each load rating prior to submission to the LRR.

The LRR and the LRE shall consider, evaluate, and verify the following items when reviewing draft load rating report submissions:

1. Load Rating Assumptions
2. Type of Structural Model Utilized
3. Selection of points/nodes to be analyzed
4. Identification & Application of Dead Loads
5. Bridge Geometric & Lane Configuration
6. Material Properties
7. Cross-Section Geometry
8. Rebar Sizing & Spacing
9. Span Length Selection
10. Dynamic Impact Reduction Factor
11. Inclusion of all Design, Legal, and Permit Vehicles
12. Average Annual Daily Truck Traffic Determination
13. Live Load Distribution Calculation
14. Selection of Legal & Permit Live Load Factors
15. Structure Condition Factor
16. Material & System Resistance Factor Selection
17. General Documentation & Comments in Input Data Files and Load Rating Report
18. Completeness of DelDOT Load Rating Forms

Any load rating that results in a recommended bridge load restriction posting shall be reviewed and approved by the BME. Refer to Section 2 – *Bridge Load Postings* of this Manual.

1.7.6 Resolution of Data, Errors, and Changes

The LRR shall communicate to the LR any errors in the data or issues with the construction plan, methodology or results. The goal is to ensure that the methodology is appropriate for the structure being load rated and that the data is accurate. Any discrepancies that cannot be resolved between the LR and LRR shall be brought to the attention of the LRE or BME for resolution.

1.8 Quality Assurance Procedures

QA procedures consist of reviewing a sample of load rating reports annually to verify the quality level of the load rating program. The results of the load rating reviews will be summarized in an annual report.

1.8.1 Quality Assurance Roles and Responsibilities

All QA activities fall under the responsibility of the BME. The load rating reviews may be performed with the assistance of the LRE.

1.8.2 Load Rating Quality Assurance Review Procedures

QA reviews shall be completed by the end of each calendar year. QA reviews shall consist of sampling, reviewing, validating, and reporting on the load ratings that have been performed in the current calendar year.

1.8.2.1 Sampling Parameters

A minimum of 5% of bridge load ratings completed in the current calendar year should be selected for QA review. The bridge load ratings should consist of a representative sample and include bridges that have been load rated by each LR or Consultant. In addition to the 5% QA review, all load ratings indicating that there is a change in the current posting restriction for a bridge or if the bridge is in Poor condition are to be reviewed by the BME.

1.8.2.2 Acceptance Criteria

The following criteria shall be used in determining acceptability of a load rating report:

1. Completeness of load rating report
2. Conformance of load rating report to this Manual
3. LRR qualifications
4. Appropriate model used for analyzing bridge structure
5. Correctness of input data
6. Bridge record updated correctly
7. Completeness of load posting resolution process, if applicable

1.8.2.3 Annual Report

An annual report shall be prepared that contains the results of the Load Rating Quality Assurance Process. The report shall include any recommendations for improvement of the load rating process along with any issues found for each bridge reviewed.

1.9 Load Rating Requirements

Load ratings are required to be completed before a new bridge is entered into the bridge inventory and opened to traffic or when a bridge is rehabilitated. Load ratings are also required when a bridge inspection reveals deterioration and/or damage that warrants a structural analysis to ascertain the impact to the strength and/or serviceability to an element of the bridge or the entire bridge. This correlates to an NBI Deck, Super, or Culvert Condition Rating of a 4 or less.

1.9.1 New Bridges

DelDOT policy is to load rate new bridges in accordance with this Manual. DelDOT policy is to design all new bridges on state-maintained roads so that load rating factors are 1.0 or greater for the AASHTO HL-93 load, AASHTO HS20-44 load, all Delaware, SHVs, and FHWA Emergency Legal Load vehicles, and Delaware Annual Permit Loads. In addition, bridges must be designed to fulfill AASHTO design load requirements for LRFD.

1.9.2 Rehabilitated Bridges

DelDOT policy is to load rate bridges that are having structural rehabilitation work activities performed that affects the loading and/or capacity for current AASHTO LRFD design loads, as well as all legal load requirements. The structural rehabilitation project may address one or a combination of the following: repair existing structural deficiencies that will return the bridge back to its original design capacity, increase the load ratings to AASHTO LRFD design load requirements, strengthen the bridge, or remove any load posting restriction.

On some rehabilitation projects, it may not be feasible to rehabilitate the structure to current AASHTO LRFD design load requirements and/or remove the load posting restriction. Some examples of when this situation could arise include projects involving historic bridges, temporary bridges, or projects with a limited scope or budget. In such cases, the bridge shall be designed to reinstate the bridge back to its original design capacity while trying to achieve rating factors greater than or equal to 1.0 as much as possible for all Delaware legal load vehicles, SHVs, and FHWA Emergency legal load vehicles. If a rehabilitated bridge does not rate successfully (i.e., rating factor < 1.0) for the AASHTO HL-93 design loads or the Delaware, SHVs, or Emergency legal load vehicle(s), the PM shall submit a Design Exception. Design Exceptions are prepared according to BDM Section 102.5.4 *Design Exceptions and Design Variances*. A rehabilitated bridge that does not rate successfully for any of the legal loads will require a load posting. This should be considered in the evaluation of the Design Exception.

1.9.3 Bridge Inspections

By law, all bridges in the NBI are required to be inspected every 24 months at a minimum. Any bridges that *do not* meet the Federal definition of a bridge but *do* meet the state definition of a bridge are required to be inspected every 48 months at a minimum. Inspection frequencies are determined by the structure type, condition, and load posting restrictions. Bridges in poor structural condition require more frequent inspections. Refer to the BIM for additional information about inspection frequency requirements. Inspection of bridges is done in conformance with the current publication of each of the following: MBE, FHWA's *Specification for the National Bridge Inventory*, BIM, and BEIM. Some structures require more detailed and different types of inspections to determine their actual condition.

Bridges are not typically load rated as a part of their routine inspections. However, load ratings of bridges during inspections are usually prompted by discovery of significant section loss, progressive deterioration, excessive deflection, and suspected loss of capacity. Field measurements obtained by the inspection team that differ from that of the plans shall be used to update the load rating. If significant deterioration is identified during the field inspection that causes concern for the load capacity of the bridge, the inspection team shall produce detailed sketches documenting the deficiencies found, so that the load rating can be re-evaluated to determine if the load-carrying capacity has been compromised.

The BMS maintains a file for each bridge, which includes bridge inventory and condition data, sketches, load rating summaries, maintenance records, and contract plans. This information indicates the current condition of the bridge, which can then be used in load rating calculations for the structural elements. A special inspection can be scheduled with the BMS if the structural deficiencies are not documented in sufficient detail in previous inspection reports.

1.9.4 Load Rating Timeline

All load ratings shall be performed within the timeframes defined below.

1.9.4.1 New and Rehabilitated Bridges

DelDOT in-house design projects are initially load rated after distribution of the Semi-Final Construction Plans. If a Consultant is responsible for the design project, they shall submit the load rating to the LRE and BME with the Semi-Final Construction Plan Submission for review and approval. Any issues arising from the load rating shall be conveyed to the designer and addressed prior to the distribution of Final Construction Plans.

The finalized Load Rating Summary Table shall be included in the Final Construction Plans in accordance with Section 1.11 – *Load Rating Report*.

Any modifications to the bridge, either through shop drawings or field changes, shall be communicated to the BMS and incorporated into the load ratings. Modified load ratings shall be submitted to the BMS prior to the completion of the project.

The load rating data will be updated by the BME for the new or rehabilitated bridge during the inventory inspection.

1.9.4.2 Condition-Based Load Ratings

Load ratings that are performed as a result of bridge inspection findings shall be completed and finalized within 28 calendar days of the inspection date. Refer to the *Inspection Activity Related Timelines* section of the BIM for additional details.

1.9.4.3 Periodic Load Rating Review

Load ratings shall be reviewed periodically and updated accordingly. Load ratings should incorporate code changes, condition changes, and loading changes. It is DelDOT's goal to strive for updating load ratings for each bridge approximately every 10 years over the life of the bridge. This is not a stringent requirement, but rather a general goal and can be adjusted as needed depending on load rating staffing resource availability and needs and on policy and code change frequencies.

1.9.5 Rated Members

DelDOT policy is to load rate only the primary load-carrying superstructure members on a bridge. This is normally the girders, trusses, floor beams, stringers, spandrel columns, arch ring, or slabs of slab bridges. Concrete box culverts and frames are also load rated. The LR must apply engineering judgement to evaluate other primary elements of a structure and include these ratings in the load rating calculation.

Gusseted and/or pinned connections of non-load-path-redundant steel-truss bridges shall be evaluated during the bridge load rating analysis. The evaluation of gusset connections shall include the evaluation of the connecting plates and fasteners.

The decks, piers, abutments, and foundations are typically not included in the load rating. Decks should be considered to the extent that they contribute to the composite strength of the superstructure. The condition of these elements shall be considered, and they shall be assumed to safely carry the loads transmitted to them, unless there is evidence of serious deterioration. Special attention and consideration shall be given to main elements and components of the substructure whose failure is expected to cause collapse of the bridge, such as fracture-critical steel pier caps, cross beams, or hammerhead piers. Refer to the MBE for guidance on load rating substructure elements.

1.10 Load Rating Procedures

This section addresses the standard load rating procedures adopted by DelDOT. These procedures include analytical steps, rating methodology, information gathering, load calculation, structural analysis, rating equation tabulation, structure specific rating guidance, and load testing.

Outlined below is the standard procedure required to load rate any member based on the internal forces in the member. The execution of the individual analytical steps within the procedure may vary depending on the analysis method. The following analytical steps are required:

1. Determine section properties
2. Determine material properties (e.g., yield strength of steel, compressive strength of concrete)
3. Calculate section capacities
4. Specify and calculate dead loads
5. Specify and calculate live loads

6. Specify and calculate live load distribution
7. Perform structural analysis and calculate the internal forces for each member
8. Calculate load rating factors

1.10.1 Load and Resistance Factor Rating

There are various load rating methods that are based on the design methods presented in various AASHTO bridge publications. DelDOT's standard method for all load ratings is the LRFR Method. Diagnostic Load Testing may be used in conjunction with the LRFR Method as required. Other methods of load rating, such as Load Factor and Allowable Stress Methods, shall only be used with the approval of the LRE.

The LRFR Method provides a methodology for load rating a bridge that is consistent with the LRFD philosophy of the BDS. This method uses load and resistance factors that have been calibrated based on structural reliability theory to achieve a minimum target reliability for the strength limit state.

Guidance is provided on service limit states that is applicable to bridge load rating. This guidance is not based on reliability theory but is based on past practice. The LRFR Method is preferred because it recognizes a balance between safety and economics. The LRFR Method is appropriate for load rating all bridges, regardless of the original criteria and method used in the design of the bridge.

The load rating practices that are consistent with this method are Design Load Rating (first level evaluation), Legal Load Rating (second level evaluation), and Permit Load Rating (third level evaluation). The load rating is generally summarized as a rating factor for each live load truck model, using the general load rating equation provided in Section 1.10.4 of this Manual.

1.10.2 Information Gathering

Prior to rating an existing bridge, the LR must gather all available data pertinent to the structure. This may require the LR to perform a site visit of the structure or, at minimum, review results from the most recent inspection. This step will aid in the selection and development of member section properties, material properties, and dead and live load effects.

The LR also needs a complete description of the bridge, as-built plans or contract plans, any modifications since it was built, and information related to its present condition. In lieu of plans, a detailed set of measurements and/or sketches from actual field measurements can be utilized. The BMS maintains a file of past inspection results for each bridge, along with maintenance records, contract plans, and other relevant information. This information indicates the current condition of the bridge, which can then be used in load rating calculations of the structural elements. The LR should contact the BIE to obtain this information.

1.10.2.1 Section Properties

Information regarding section properties may be obtained from as-built plans or contract plans, if available. Additionally, the LR shall review all plans, shop drawings, and repair projects to confirm any structural repairs that may have been completed to ensure the load rating accurately reflects the current condition of the bridge.

Structural members should be field measured when contract plans are not available or lack in detail. Refer to the *Bridges with No Plans* section of the MBE for guidance when details are not available from plans or field measurements.

When conditions warrant, reduced sections should be used to obtain a load rating that best reflects the known condition and capacity of the structure. Areas of deterioration must be given special attention and accounted for in the load rating, as a primary load carrying member that is reduced in section may control the capacity of the structure. If necessary, the LR may request additional section loss measurements or detail by contacting the BIE.

1.10.2.2 Material Properties

Information concerning material properties may be obtained from as-built or contract plans, guidelines found in the MBE, or material testing. Due to the wide variety of structural materials available, assortment of structure types, and variation in quality and strength of materials, the LR may need to make assumptions to analyze existing bridges. All assumptions shall be documented in the Load Rating Report. If necessary, the LR may request material testing by contacting the LRE. For additional information regarding material testing, refer to the *Materials Testing* section of the BDM. For new structures, standard design criteria presented in the BDS, and contract plans shall be used.

1.10.3 Loads

Only two types of loads are typically considered when load rating a bridge: dead load and live load. For structures that are partially or completely buried, horizontal and/or vertical earth loads shall also be considered.

1.10.3.1 Dead Loads

Dead loads include the weight of the bridge and anything that is permanently attached to the deck or superstructure. In LRFR, these loads are separated into two types: structural components and attachments (DC); and wearing surface and utilities (DW). All dead loads should be based on dimensions shown on the plans and verified with field measurements, as needed. Unit weights may be obtained from the BDS. The presence of utilities, sign structures, light poles, and other attachments shall be verified by plans, photos, or field visit prior to performing a load rating. The allowance for a future wearing surface should *not* be included. Refer to the *Distribution of Dead Loads* section of the BDM for guidance regarding distribution of concrete bridge railing.

DC Loads

- The ½" integral wearing surface is *not* considered part of the structural deck thickness. It shall be included as Sacrificial Topping Thickness.
- Verify the existence of SIP forms by plans, photos, or field visit. Enter as a deck uniform load with a unit weight of 15 psf, which includes the forms and the concrete in the form corrugations.
- For Parapets/Fencing/Guardrail/Curbs/Medians, use a unit weight that is appropriate for the material. If the load is applied after the deck has cured, i.e., Stage 2, the loads shall be distributed with 75% to exterior and 25% to interior beams. When rating existing bridges that do not rate for the exterior beam, LR shall re-evaluate the rating by applying the load equally to all beams.
- Light Poles - Weight of light poles that are attached to the parapet/sidewalk and placed after the deck has cured should be included with the dead load of the parapet/sidewalk.
- Sign Structures - Sign structure load shall be placed on the beam(s) that they are attached to. Check for additional support members in the first interior bay.

DW Loads

- Hot mix or concrete protective overlays placed on top of an existing deck, at any time after the deck has cured are to be treated as DW and are *not* considered part of the structural deck thickness.
- Utilities – Use a unit weight which is appropriate for the material. Apply the lever rule to distribute utility loads when utilities are affixed to diaphragms beneath the bridge.

1.10.3.2 Live Loads

As related to trucks, a bridge's capacity depends not only on the gross weight, but also on the number and spacing of the axles and the distribution of load between the axles. Load ratings shall be performed for Design, Legal, and Permit vehicles. Pedestrian live load on sidewalks shall *not* be considered in the load rating of the bridge.

In cases when a live load distribution factor obtained from AASHTO does not result in a satisfactory load rating, the LR can use a refined analysis method (i.e., FEM) to calculate the live load distribution factors, with approval from the LRE.

Design Loads

Design Loads include the HL-93 and the HS20-44 live loads as defined in the MBE.

The HL-93 load consists of the design truck or design tandem in combination with the design lane load applied to the bridge as follows:

- The effect of the design tandem combined with the effect of the design lane load, or
- The effect of one design truck with the variable axle spacing, combined with the effect of the design lane load, and
- For negative moment between points of contraflexure under a uniform load on all spans and reaction at interior piers only, 90 percent of the effect of two design trucks spaced a minimum of 50.0 ft between the lead axle of one truck and the rear axle of the other truck, combined with 90 percent of the effect of the design lane load. The distance between the 32.0-kip axles of each truck shall be taken as 14.0 ft. The two design trucks shall be placed in adjacent spans to produce maximum force effects.
- Axles that do not contribute to the extreme force effect under consideration shall be neglected.

Although the HS20-44 live load is not an LRFD load in the BDS, it is included as a design load for use in the overweight permit process. Refer to the permit loads guidance provided in Section 3 of this Manual for more information on permits. The HS20-44 live load shall be applied as the Standard HS Truck and the Standard Lane Load as defined in the MBE. These loads are entered individually in the analysis software, and both loads are identified as notional loads.

Design Load Ratings shall be performed at inventory level and operating level for all design loads, in accordance with the MBE.

Legal Loads

For simplicity, Delaware's highway bridges are load rated for six standard legal loads, which are representative of actual vehicles on the highways. The MBE contains procedures for rating the following types of legal loads:

- Routine Commercial Traffic
- Specialized Hauling Vehicles (SHV)

The MBE requires that bridges be load rated for the Type 3, Type 3S2, and Type 3-3 AASHTO legal vehicles and lane-type loads for routine legal commercial traffic. The AASHTO legal loads are sufficiently representative of average truck configurations in use today. However, the MBE allows load ratings to be performed for state legal loads that only have minor variations from the AASHTO legal loads. DelDOT has elected to use the state legal loads as defined in the Delaware Code in lieu of the AASHTO legal loads.

DelDOT's standard legal loads are the S220, S335, S437, T330, T435, and T540. DelDOT's legal loads are applied to the bridge in the same manner as the AASHTO legal loads. The critical load effects are taken as the larger of the following:

- For all load effects, a single state legal load.
- For negative moments and reactions at interior supports, a lane load of 0.2 klf combined with two state legal loads multiplied by 0.75 traveling in the same direction separated by 30 feet.
- For span lengths greater than 200 feet, a single state legal load multiplied by 0.75 combined with a lane load of 0.2 klf.

Refer to Appendix 1-1 for the state legal load configurations and axle loading.

In addition to Delaware legal loads, the AASHTO SHV's (SU4, SU5, SU6, SU7) must also be included in the load rating. DelDOT does not perform load ratings for the notional rating load (NRL). Only one SHV is applied per lane, and lane loads are not included. SHV configurations and axle loading are included in the MBE.

The FAST Act also requires rating for the EV2 and EV3 axle configurations. The critical load effects for the EV's are determined in the same manner as described for the state legal loads. Refer to Appendix 1-1 for the EV2 and EV3 configurations and axle loading.

If any of the legal loads result in a load rating factor < 1.0, then a load posting in accordance with Section 2 of this Manual will be required. If the S335 legal load has a load rating factor < 1.0, this vehicle may be re-rated as a routine permit vehicle as per the MBE, subject to approval by the BME.

If the bridge requires posting for any of the standard Delaware legal vehicles, SHV's, or EV's, then the FL77, FE46, FE54, and FR50 Delaware-specific emergency vehicles and B216 and B218 busses shall be load rated to determine what effect the posting restriction has on those vehicles. The critical load effects for these vehicles are determined in the same manner as described for the state legal loads. The live load factors for emergency vehicles may be modified in accordance with Section 1.10.4.3. Refer to Appendix 1-1 for the emergency vehicle and bus configurations and axle loading. Posting for the FL77, FE46, FE54, and FR50 emergency vehicles and B216 and B218 busses is not required. Refer to Section 2 of this Manual for further guidance. If a particular fire department's vehicle or local bus loads and/or axle spacings differ from the vehicles identified in Appendix 1-1 then those axle loads and configurations may be used for analysis upon approval of the LRE.

Permit Loads

DelDOT's Oversize/Overweight (OSOW) Permit Program allows application for operation of vehicles that exceed the legal load limitations. The BMS reviews permit applications for

Superloads, which are vehicles with GVW exceeding 120,000 pounds *or* with any individual axle weight exceeding 25,000 pounds. Occasionally, a Permit Load Rating is required for a Superload on a specific bridge as outlined in Chapter 3 of this Manual. The OSOW Permit Program also allows for OSOW Annual Crane Permits. These permits allow restricted movement of cranes that exceed the legal load limitations with applicable provisions and are reviewed in a similar manner as Superloads. Refer to Chapter 3 of this Manual for more information about the screening process for Superloads and Annual Crane Permits.

For simplicity, Delaware's highway bridges are load rated for four standard permit loads, which are representative of the allowable Annual Crane Permit vehicles. DelDOT's standard Permit Loads are AC2, AC3, AC4, and AC5 (see Appendix 1-2). The standard permit loads have been developed to check the safety and serviceability of newly designed bridges and existing bridges as part of the load rating process. The critical load effects are determined as follows:

- For spans up to 200 feet, only the permit vehicle shall be considered present in the lane.
- For spans between 200 feet and 300 feet and when checking negative moments in continuous span bridges, a lane load of 0.2 klf shall be applied simultaneously with the permit vehicle.

Dynamic Load Allowance

The dynamic load allowance specified in BDS shall be applied to the load ratings. The dynamic load allowance shall be modified for structures under fill or wood components, as specified in BDS. The dynamic load allowance shall *not* be applied to lane loads.

The dynamic load allowance specified for design loads deliberately reflects conservative conditions that may prevail under certain distressed approach and bridge deck conditions with bumps, sags, or other major surface deviations and discontinuities. For longitudinal members having spans greater than 40 feet with less severe approach and deck surface conditions, the dynamic load allowance may be decreased for legal and permit ratings, in accordance with the MBE *Dynamic Load Allowance: IM* section. The LR shall only apply the reductions after a field review of the approach and deck surface conditions. Consideration can also be given to reducing the dynamic impact for bridges that have reduced or lower speed limits as per the MBE. Consult with the LRE for approval and additional guidance.

1.10.3.3 Live Load Distribution

Live load distribution shall be as per BDS. Bridges for which accurate live load distribution formulas are not readily available may be analyzed by refined methods of analysis, as per the BDS. In some instances, live load distribution may be modified based on the results of load testing done in accordance with Section 1.10.5 of this Manual – *Diagnostic Load Testing* and the MBE.

1.10.3.4 Earth Pressure

Earth pressure loads are separated into four types: vertical pressure from dead load of earth fill (EV); horizontal earth pressure (EH); earth surcharge load (ES); live load surcharge (LS). For typical unit weights and further guidance on calculation of various earth pressure loads, refer to the BDS. It should be noted that BRASS is not capable of incorporating the appropriate load factors for EV, EH, ES, and LS loads. Refer to structure specific rating guidance in subsequent sections of this Manual for application of earth pressure loads.

1.10.4 General Load Rating Equation

Per the MBE, the following general expression shall be used in determining the load rating of each component and connection for each force effect (i.e., axial force, flexure, or shear):

$$RF = \frac{C \pm (\gamma_{DC})(DC) \pm (\gamma_{DW})(DW) \pm (\gamma_{EV})(EV) \pm (\gamma_{EH})(EH) \pm (\gamma_{ES})(ES)}{(\gamma_{LL})(LL+IM) \pm (\gamma_{LS})(LS)}$$

For Strength Limit States:

$$C = \phi_C \phi_S \phi R_n$$

Where the following lower limit shall apply:

$$\phi_C \phi_S \geq 0.85$$

For Service Limit States:

$$C = f_R$$

Where:

RF = Rating Factor

C = Capacity

f_R = Allowable stress specified in the BDS

R_n = Nominal member resistance (as inspected)

DC = Dead load effect due to structural components and attachments

DW = Dead load effect due to wearing surface and utilities

EV = Vertical Earth Pressure (see Sections 1.10.8.3 and 1.10.8.4)

EH = Horizonal Earth Pressure (see Sections 1.10.8.3 and 1.10.8.4)

ES = Uniform Earth Surcharge (see Sections 1.10.8.3 and 1.10.8.4)

LL = Live load effect

IM = Dynamic load allowance

LS = Live load surcharge (see Sections 1.10.8.3 and 1.10.8.4)

γ_{DC} = LRFD load factor for structural components and attachments

γ_{DW} = LRFD load factor for wearing surface and utilities

γ_{EV} = LRFD load factor for vertical earth pressure (see Sections 1.10.8.3 and 1.10.8.4)

γ_{EH} = LRFD load factor for horizontal earth pressure (see Sections 1.10.8.3 and 1.10.8.4)

γ_{ES} = LRFD load factor for earth surcharge (see Sections 1.10.8.3 and 1.10.8.4)

γ_{LL} = Evaluation live load factor

γ_{LS} = LRFD load factor for live load surcharge (see Sections 1.10.8.3 and 1.10.8.4)

ϕ_C = Condition factor

ϕ_S = System factor

ϕ = LRFD resistance factor

The load rating shall be carried out at each applicable limit state and load effect, with the lowest value determining the controlling rating factor. Refer to the MBE for additional guidance regarding loads and load effects.

1.10.4.1 Limit States

Strength is the primary limit state for load rating. Service limit states shall be checked in accordance with the provisions of the MBE, including those listed as optional checks. It is not necessary to check the Fatigue limit state for steel bridges, unless prompted by inspection findings. The LRE shall be responsible for determining if checking the Fatigue limit state is necessary.

1.10.4.2 Load Effects

Members shall be evaluated for axial, flexure, shear, and combination of axial and flexure, as appropriate. Shear shall be evaluated for all concrete structures. When using the Modified Compression Field Theory (MCFT) for the evaluation of concrete shear resistance, the longitudinal reinforcement shall be checked for the increased tension caused by shear. The MCFT is equivalent to the general procedure in the BDS.

1.10.4.3 Load Factors

Load factors for design loads are defined in the MBE. The MBE provides generalized load factors for legal load rating that are appropriate for use with DelDOT Legal Loads. These load factors are also used for SHV and Emergency standard legal loads. In general, the Delaware specific emergency vehicles and busses should be load rated as legal loads. However, if the rating factors for any of those legal loads are < 1.0, the live load factors for those vehicles may be reduced as recommended by National Cooperative Highway Research Project (NCHRP) 20-07 Task 410 as outlined in the DelDOT Action Plan: FAST Act for Emergency Vehicles. These legal load factors are included in Appendix 1-3. The legal loads should be re-rated based on the reduced live load factors, and the corresponding outcome should be used as final rating factors.

Permit load factors for Routine or Annual Permits with Unlimited Crossings shall be used for DelDOT's standard permit loads as defined in the MBE.

Use the latest DelDOT Traffic Summary to determine AADT and truck percentages. The summary can be found at:

http://deldot.gov/information/pubs_forms/manuals/traffic_counts/index.shtml

1.10.4.4 Condition Factor, φ_c

The condition factor provides a reduction to account for the increased uncertainty in the resistance of deteriorated members and the likely increased future deterioration of these members during the period between inspection cycles. The condition factors provided in the MBE shall be applied based on the most recent superstructure or culvert NBI condition rating.

Improved inspections will reduce, but not eliminate, the increased resistance variability in deteriorated members. If section properties are obtained accurately, by actual field measurement of losses rather than an estimated percentage of losses, the values specified for Condition Factor (ϕ_c) may be increased by 0.05 ($\phi_c \leq 1.0$) in accordance with the MBE.

1.10.4.5 System Factor, φ_s

System factors are multipliers applied to the nominal resistance to reflect the level of redundancy of the complete superstructure system. Bridges that are less redundant will have their factored member capacity reduced and, accordingly, will have lower ratings.

Subsystems that have redundant members shall not be penalized if the overall system is nonredundant. Thus, closely spaced parallel stringers would be redundant even in a two-girder bridge with closely spaced multiple floor beams and stringers.

System factors shall only be applied when checking flexural and axial effects at the strength limit state. The system factors given in the MBE shall be applied, not those found in the BDS.

1.10.4.6 Resistance Factors

A resistance factor is a statistically based multiplier applied to the nominal resistance accounting primarily for variability of material properties, structural dimensions and workmanship, and uncertainty in the prediction of resistance, but also related to the statistics of the loads through the calibration process. Resistance factors shall be applied to the strength limit state as specified in the BDS, based on material and load effect.

1.10.5 Diagnostic Load Testing

When a load rating indicates a bridge requires posting, diagnostic load testing may be used to more accurately estimate parameters used during the structural analysis such as load distribution, support fixity, composite action, etc. The use of diagnostic load testing requires approval from the LRE. Diagnostic load testing may be deemed appropriate in the following special cases:

1. When analytical results provide a rating factor < 1.0, but the bridge is otherwise showing no visual signs of distress.
2. When record construction plans for the bridge are not available or do not have sufficient detailed information.

Diagnostic load testing is typically performed by driving a truck of known axle weights over a bridge. Strains are then measured in the load-carrying members with strain gages and specially designed data analysis equipment. Stresses are computed using the measured strains and material properties. The axle weights and computed stresses are used to calibrate the structural analysis model. A more realistic rating of the bridge can then be obtained for all loads. Further guidance for load testing is provided in the MBE.

1.10.6 Structural Analysis and Tools

Structural analysis and load ratings are prepared for each typical primary load-carrying superstructure member of each structure unit. Refer to Section 1.9.5 of this Manual for additional information regarding load rated members. A structure unit consists of either a simple span or a series of continuous spans. Each structural analysis should be representative of the structure's span lengths, section properties, and distribution of loads. In general, all span units and associated beams shall be included in the load rating analysis. For multi-beam line analysis with uniform beam spacings, span lengths, span configurations, and cross sections there should be, at a minimum, an interior and an exterior girder load rating. For beams with variable spacings but same cross sections, the interior and exterior beams associated with the largest spacings should be rated. Likewise, a slab analysis should include an interior section and an exterior section of the slab. Duplicate load ratings are not required for identical structure units; however, this shall be documented in the load rating report. Engineering judgment may be used to eliminate the need to rate similar structure units, but this shall be approved by the LRE and documented in the load rating report.

Several computer programs are available for structural analysis of bridges. Wyoming Department of Transportation's BRASS-GIRDER™ computer program, herein referred to as BRASS, is the standard program used by DelDOT to rate bridges and shall be used whenever possible. BRASS is a line girder analysis program and as such is capable of rating straight steel, reinforced and pre-stressed concrete, and timber girder structures, as well as concrete slabs, timber slabs, and concrete rigid frame structures. BRASS also has the capability to rate floorbeams and stringers in such structures. Although BRASS can be used to analyze some buried structures, special consideration must be given to the load factors used, as they might not be synonymous with non-buried structures. Refer to Section 1.10.4.3 for guidance on load factor modifications. Other buried structures, such as pipe culverts, can be load rated using hand calculations and/or spreadsheet-based calculations. Refer to Table 1-2 in Section 1.10.8.3 for Earth Load Correction Factors.

Structures with large skews or curvature shall not be analyzed by line girder analysis, as specified by the BDM section titled *Determination of Appropriate Analysis Method using NCHRP Report 725*. For structure types that cannot be analyzed with BRASS, one of several finite-element programs may be used to perform the structural analysis. Bentley's STAAD.PRO® and MDX Software are the two programs preferred by DelDOT. Other structural analysis programs may be used with the approval of the LRE. These analysis programs may be used in conjunction with hand calculations and/or spreadsheet-based calculations to complete the load rating, in accordance with this Manual. The LR shall clearly understand the basic assumptions of the program and the methodology that is implemented. Sufficient documentation of the software input and output files shall be provided to allow verification of the results.

Table 1-1 below summarizes the recommended software to complete a load rating analysis for various structure types. It should be noted that the *Alternate Software* column is not an exhaustive list of acceptable load rating software programs. Other programs may be utilized with prior consent of the LRE.

Table 1-1 Load Rating Software Guidance Table

Structure Type	Preferred Software	Alternate Software
Reinforced Concrete Beam	BRASS	-
Prestressed Concrete Beam	BRASS	-

Concrete Slab Bridge	BRASS	-
Concrete Box Culvert & Frame Culverts	BRASS	Reinforced Concrete Moment Frame Culvert Analysis Spreadsheet
Reinforced Concrete Arch Structures	STAAD	LRE Approval
Segmental Structures	LRE Approval	-
Longitudinal Steel Girders	BRASS	MDX
Girder-Floorbeam-Stringer Structures	BRASS	STAAD
Trusses	STAAD	LRE Approval
Steel Box Girders	MDX	LRE Approval
Curved & Highly Skewed Girders	MDX	STAAD
Connections	STAAD	LRE Approval
Timber Stringers	BRASS	-
Glulam & Nail Laminated Wood Panels	DelDOT Mathcad Timber Slab Analysis Program	BRASS, Spreadsheet
Reinforced Concrete Pipe	Pipe Culvert Load Rating Procedures	LRE Approval
Metal Pipe, Pipe Arch	Pipe Culvert Load Rating Procedures	CMP Analysis Spreadsheet
Thermoplastic Pipes	Pipe Culvert Load Rating Procedures	LRE Approval
Masonry Structures	Bridges Without Plans Procedures	LRE Approval

1.10.6.1 File Naming Convention

Data file names shall consist of:

For single span: C-NUM_girder designation.xxx

For multiple span: C-NUM_s#_girder designation.xxx where:

C = County Code (1, 2, or 3 for New Castle, Kent, and Sussex Counties, respectively)

NUM = Three-digit bridge number (add a fourth digit suffix to bridge number if required)

= Span number(s)

Girder designation = description of girder rated

The girder designation may be “int” or “ext” for typical interior or exterior girders. Girder numbers may also be used to designate a specific girder. The girder number shall match the construction plans.

Example (BRASS): 1-123_s1_int.girder
1-123_s1_g3.girder
1-123_ext.girder
1-123A_s2-s4_int.girder

Do not use a space or special characters in the data file name.

1.10.6.2 BRASS

BRASS data is input through a graphical user interface (GUI). The GUI stores the structure and loading description to a file that is given a *.girder* extension. This file is used to define a girder and its loads. This file should be archived for the structure definition, i.e., it is the data file. BRASS provides a vehicle library file (.blv) which includes AASHTO Design and SHV’s, as well as DelDOT standard legal and permit loads. A library file for current and historical structural sections (.bls) is also provided.

BRASS Data File Migration

When updating load ratings for bridges that have existing BRASS LRFR files, the BRASS .dat file may be migrated into the BRASS GUI version. As part of this, an additional QC check needs to be completed by the LR and LRR to ensure that the data has transferred successfully and that all errors given by the BRASS GUI program have been resolved.

BRASS GUI Data Entry

The BRASS GUI program shall be used when load rating bridges for design projects involving a new bridge or for an existing bridge that currently does not have a LRFR rating. The LR is responsible for verifying each input field is correctly entered into the GUI. The input fields are color-coded and described as follows:

- White – The field is required and may be edited.
- Light Yellow – The field is optional and may be edited. The BRASS engine will set any necessary default. The help topic for each form will list default information.
- Light Green – The field is calculated and may be edited. The BRASS engine will calculate the value, which is generally based on an AASHTO equation.
- Gray – The field is read-only, i.e., it may not be edited. The GUI automatically populates this field. In several instances, the GUI will calculate a value for this field.

The LR should pay attention to the default values for each field. If a yellow or green field default value is acceptable, the field may be left blank.

The administration tab shall include standard information, such as the load rating agency, LR, bridge number, bridge location information, bridge type, span number, beam designation, and contract numbers. Provide adequate information such that the load rating summary can be completed.

Refer to Appendix 1-7 for additional guidance to using the BRASS-GIRDER load rating software.

1.10.7 Safe Posting Load

Safe posting load serves as a guideline for establishing a posting weight limit for a structure. The safe posting load will typically be less than the load determined in the legal load rating. The following formula from the MBE will be used to determine the safe posting load for each vehicle type:

$$Safe\ Posting\ Load = \frac{W}{0.7}[(RF) - 0.3]$$

Where:

RF = Legal load rating factor

W = Weight of rating vehicle (kips)

Applicable values for RF are between 0.3 and 1.0. If a rating factor for any vehicle type falls below 0.3, then that vehicle type should *not* be allowed on the span.

The Safe Posting Load is calculated in the *Posting Weight Summary Form*. Reference Section 2 of this Manual for additional guidance on load posting.

1.10.8 Concrete Bridge Load Ratings

The information below is supplemental to the general load rating procedure as it specifically applies to concrete bridge structures. Refer to Section 1.10 of this Manual for guidance on section properties, material properties, load factors, and general load rating procedures.

Limit States - For design loads and legal loads, reinforced concrete components should be load rated for the *Strength I* limit state. For permit loads, concrete bridge components should be load rated for the *Strength II* limit state. Refer to the MBE *Limit States and Load Factors for Load Rating Table*.

1.10.8.1 Prestressed Concrete Beam Bridges

This section outlines the methodology for load rating prestressed concrete beam bridges. Below is guidance which specifically applies to these analyses.

Bridge Model/Configuration

The following guidance shall be used when modeling a prestressed concrete beam bridge:

A prestressed beam with circular voids shall be treated as a voided slab when using BRASS for the load rating. A prestressed beam with a rectangular opening shall be load rated as a box beam.

Limit States

The following limit states shall be used when load rating prestressed concrete beam bridges:

- Design Live Loads should be rated for the *Strength I* and the *Service III* limit states. However, Design-Live Loads do not need to be rated for *Service III* at operating level.
- Legal Live Loads should be rated for *Strength I* and *Service III* limit states. The *Service III* limit state is used in design to limit the tensile stresses of fully prestressed concrete members based on uncracked sections. If the load rating is controlled by the *Service III* limit state and the bridge does not exhibit cracking under normal traffic, this limit state may be neglected with approval of the LRE.
- Permit Live Loads should be rated for *Strength II* and *Service I* limit states.
- When determining tensile stress limits in concrete under service limit states, unless specified otherwise in the contract plans, bridges spanning water shall be considered in *severe corrosive conditions*. If the bridge does not rate successfully for the design or legal load vehicles (i.e., RF < 1.0), consideration can be given to rate the bridge using *moderate corrosive conditions* as approved by the LRE. Bridges not spanning water shall be considered in *moderate corrosive conditions*, unless otherwise directed by the LRE or specified in the contract plans.
- Refer to the BDS *Prestress Losses* section for equations for calculating prestress losses.

Material Properties

If strand type is unknown, perform one load rating using stress-relieved (STR) strands and a second using low relaxation (LR) strands. The more conservative load rating shall be used, except in the case when the load rating results in a bridge posting in which further evaluation is required. In such instances, incorporate field verification or review latest inspection report to evaluate if any transverse cracking, camber loss, or other prestressing related deterioration is present. If no prestressing deterioration exists, use the less conservative strand type. If bridge posting is still required, refer to Section 2 of this Manual.

1.10.8.2 Concrete Slab Bridges

This section outlines the methodology for load rating concrete slab bridges. Below is guidance which specifically applies to these analyses.

Bridge Model/Configuration

The following guidance shall be used when modeling a concrete slab bridge:

- Rigid frame type culverts with limited rebar on the side walls shall be analyzed and load rated based upon the rigid frames method first as per Section 1.10.8.3 of this Manual. If the ratings are not satisfactory, rigid frame culverts may be analyzed as slab bridges. Refer to the plans to determine fixity for the analysis. In general, pin fixities (i.e., fixed against vertical and/or horizontal movement but free to rotate) are assumed at the supports. For multi-span bridges that have sufficient rebar to resist negative moment above the pier, the internal fixities can carry moment. If the slab above the pier doesn't have adequate rebar to carry negative moment, the continuous slab may be analyzed/load rated as simple span.
- If the bridge has a configuration as shown in Figure 1-2 below and Section 1.10.8.4 and requires posting when modeled as a rigid frame or as a slab, perform load rating using Reinforced Concrete Moment Frame Culverts Analysis Spreadsheet (refer to Section 1.10.8.4 below).
- Slab span lengths are generally measured from geometric center of abutment walls. For abutment walls that have widths > 12", a minimum of 6" may be used if the load rating for the bridge requires the bridge to be posted as long as approved by the LRE.
- Use rebar development length in the cross-section layout as per the BDS.

Loads

If plans do not indicate fill height or there is evidence fill height does not match the plans, field verification of the fill height is required.

- **Dead Loads –** Initial load rating run/draft shall use maximum fill and pavement heights for the dead load calculation. If the bridge requires posting, then the average fill and pavement heights may be used as per the approval of the LRE. The weight of the railing, curbs, and asphalt shall be uniformly distributed over the width of the concrete slab bridge.

- **Live Loads -** Analyze interior strip and edge beam when wheel loads travel within 24" of the end of culvert.

  Legal Load – For a culvert being rated as a slab, slab distribution equations shall be used.

  Permit Load – For a culvert being rated as a slab, slab distribution equations shall be used.

  Dynamic Load Allowance - Use minimum fill and pavement heights for live load and impact calculation. If the slab does not rate, an average fill and pavement heights for live load and impact may be considered.

- **Live Load Distribution through Fill –** For slab bridges with greater than 2' fill, refer to BDS *Distribution of Wheel Load through Earth Fills*. In this case, the axle loads shall be approximated as equivalent discreet point loads calculated by spreadsheet or other method to distribute the load through the fill transversely. Refer to the BDS to determine the live load distribution factor based upon the structure fill height.
  For slab bridges with less than 2' fill, refer to BDS *Equivalent Strip Widths for Slab-Type Bridges*.
  When load ratings are not satisfactory using LRFD distribution factors, the distribution factors may be modified based on the recommendation of the University of Delaware research report, *Effective Width of Concrete Slab Bridges in Delaware.* Consult LRE for guidance and obtaining a copy of the report.

Load Effects

- **Moment –** For a continuous slab bridge, if a haunch exists and negative moment controls the load rating, then the negative moment shall be checked at the intersection of the haunch and the uniform depth member.
- **Shear –** Shear should be evaluated at the critical section, where d_v is the greater of 0.9d and 0.72 h, where d is the distance from top of slab to the center of the bottom matt of rebar and h is the depth of the slab. If a haunch exists, the critical section is taken at $0.5d_v$ from the face of the change in slab thickness (the intersection of the haunch and the uniform depth member). If no haunch exists, the critical section is taken at d_v from the face of wall. Consider the general procedure (MCFT) and longitudinal reinforcement checks initially. If the structure

does not rate with the general procedure and the slab thickness is less than 16”, follow the simplified procedure.

1.10.8.3 Three-Sided Frame Culvert Bridges

This section outlines the methodology for load rating three-sided frame culverts. Below is guidance which specifically applies to these analyses.

Bridge Model/Configuration

The following guidance shall be used when modeling a three-sided frame culvert bridge:

- Analyze the structure as a three-sided rigid frame. The top corners are free to move and rotate. For precast three-sided culvert structures, the bottom corners are fixed against movement and free to rotate. For cast-in-place structures, with sufficient rebar connecting the walls to the footings and sufficient foundation resistance, the bottom corners are fixed against movement and rotation.
- Live load distribution factors for the slab are the same as the live load distribution factors for the walls.
- If the load rating is inadequate at the corners and/or at some points of the walls, consider rating the structure as a simply-supported slab or consider performing a diagnostic load test as approved by the LRE. If rating as a slab refer to Section 1.10.8.2, *Concrete Slab Bridges*, of this Manual.
- If a three-sided frame culvert doesn’t rate successfully for any one or more legal load vehicle and the structure meets the general rebar cross-section/layout as shown in Figure 1-2 in Section 1.10.8.4 below, the structure should be rated using the Reinforced Concrete Culvert Rating Spreadsheet (refer to the Section 1.10.8.5 below).
- Span lengths are measured from geometric center of members.
- Use rebar development length in cross section layout as per the BDS.

Loads

Figure 1-1 illustrates typical forces acting on a three-sided frame culvert. Each load acting on the culvert is discussed in greater detail below.

- **Dead Loads –** Dead loads include the self-weight of the structure. Do not include headwall and parapet loads in this analysis.
- **Earth Pressure Loads** – Refer to the MBE for the modified general load rating equation that includes the EV, EH, ES, and LS loads for culverts. BRASS is not capable of accounting for the appropriate factors for EV, EH, ES, and LS loads; therefore, these loads shall be entered into BRASS as DW loads with the appropriate correction factor. Table 1-2 below summarizes these correction factors.

Earth pressure may reduce the effects of other loads and forces on the structure. BRASS accounts for these reduced effects with the minimum and maximum load factors for DW.

For the earth pressure calculations, apply maximum fill depth and pavement heights. If the structure does not rate, apply the average fill and pavement depths.

EV - Vertical Pressure from Dead Load of Earth Fill

- Assume unit weight of 120 pcf, unless otherwise documented

EH - Horizontal Earth Pressure Load

- Assume unit weight of 120 pcf, unless otherwise documented.
- Use at rest earth pressure coefficient, $k_0 = 1\text{-}\sin\phi'_f$. Use $\phi'_f = 30^\circ$ ($k_0 = 0.5$) unless soil testing has been performed.
- Apply as linearly distributed load.

ES - Earth Surcharge

- Represents a constant lateral earth pressure from fill above the top slab of the culvert.

LS - Live Load Surcharge

- Apply as *uniformly* distributed load on the retained soil

Table 1-2 Earth Load Correction Factors

Load	Correction Factor
EV	0.9
EH, ES	0.9
LS	1.17

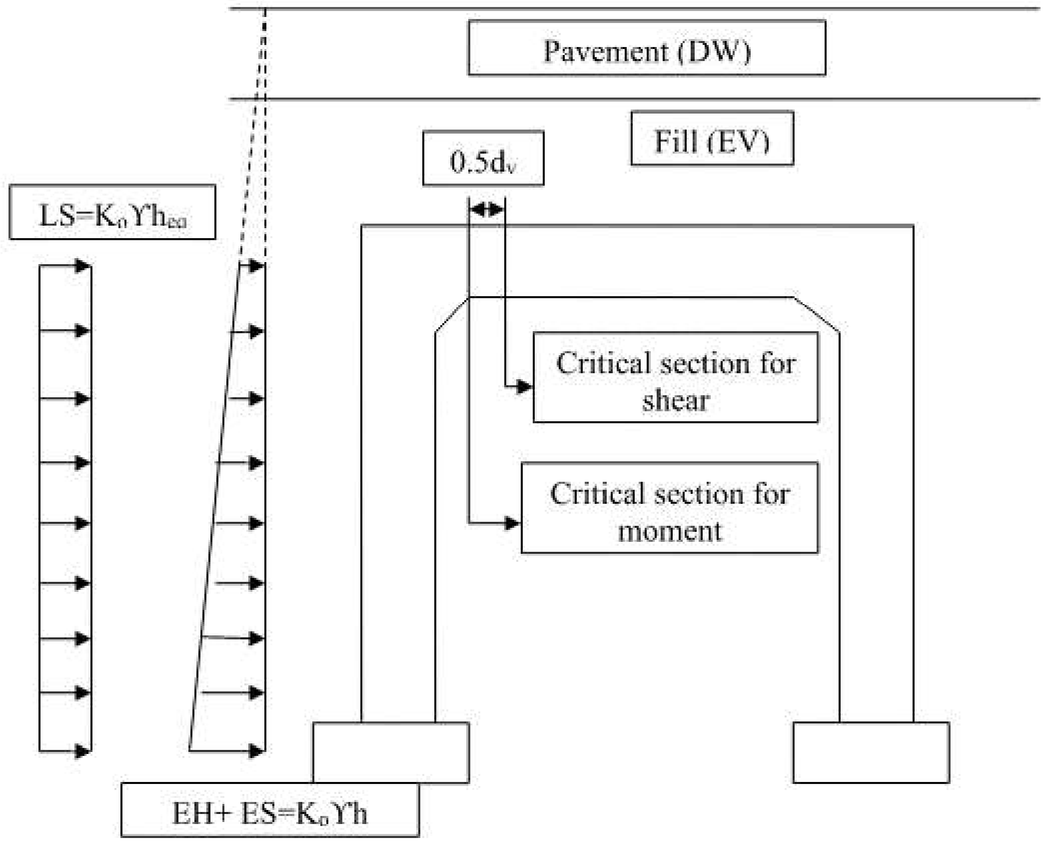


Figure 1-1 Typical Culvert Loading

Live Loads

Live loads shall be applied to the structure as specified in BDS – *Distribution of Wheel Load through Earth Fills.* All Live Loads shall be analyzed for single loaded lane and include the single lane multiple presence factor.

Design Load - Design Load Ratings shall be calculated for the HL-93 Truck, HL-93 Tandem, HS20 Truck, and HS20 lane. For spans < 15', lane load shall not be applied to the HL-93 Truck or Tandem.

Dynamic Load Allowance – For the live load and impact calculation, apply minimum fill depth and pavement heights. If the culvert does not rate, apply the average fill and pavement depths. Dynamic load allowance is not considered for culverts with > 8' of fill (i.e., 0% Dynamic Impact).

Live Load Distribution through Fill: Refer to the BDS for guidance on distribution of fill and live load distribution factors. When fill is > 2', live loads may be approximated as equivalent discreet point loads calculated by spreadsheet or other method and the multiple presence factor of 1.2 shall be included. The vertical live load should be applied as a moving load across the top of the culvert structure.

Consult with the LRE for single-span culverts with fill depth > 8' and span lengths exceeding the fill depth and for multi-span culverts where the depth of fill exceeds the distance between faces of end walls.

Limit States

For the design loads and legal loads, the culvert should be load rated for the *Strength I* limit state. For permit loads, the culvert should be load rated for the *Strength II* limit state. Refer to the MBE *Limit States and Load Factors for Load Rating Table*.

Load Effects

Culvert structural members should be evaluated for flexure, shear, and axial thrust. Load ratings at several critical sections for the culvert must be calculated for each load effect to establish the lowest load rating.

- **Moment –** If a haunch exists and negative moment controls the load rating, then the negative moment shall be checked at the intersection of the haunch and the uniform depth member.
- **Shear –** Shear should be evaluated at the critical section, where d_v is the greater of 0.9d and 0.72h, where d is the distance from top of slab to the center of the bottom matt of rebar and h is the depth of the slab. If a haunch exists, the critical section is taken at $0.5d_v$ from the face of the change in slab thickness (the intersection of the haunch and the uniform depth member). If no haunch exists, the critical section is taken at d_v from the face of wall. Consider the general procedure (MCFT) initially, including the longitudinal reinforcement check. Otherwise, the simplified procedure may be used for depths 16.0 inches or less.
- **Axial Thrust –** If the axial demand is lower than 10 percent of factored nominal compressive strength then factored bending moment load can be checked for factored flexural resistance without considering the axial-flexural interaction.

Load Factors

Live Load factors shall be determined in accordance with section 1.10.4.3 of this manual. The Legal Load Factor of 2.0 specified in the MBE for Box Culverts need not be applied to three-sided frame culverts. Instead, the generalized Legal Load Factor specified in the MBE shall be used.

1.10.8.4 Box Culvert

This section outlines the methodology for load rating box culverts. Below is guidance which specifically applies to these analyses.

Bridge Model/Configuration

The following guidance shall be used when modeling a box culvert bridge:

- A box culvert with the bottom slab may be analyzed as a three-sided rigid frame. The fixities at the bottom of the legs should be initially considered to be free to rotate. If adequate reinforcing tying the bottom slab and walls together exists, then the structure could be considered restricted for rotation, provided it is properly documented in the load rating.
- If the load rating is inadequate at the corners and/or at some points of the walls, consider rating the structure as a simply-supported slab or consider performing a diagnostic load test as approved by the LRE. If rating as a slab refer to Section 1.10.8.2, *Concrete Slab Bridges*, of this Manual.
- Span lengths are measured from geometric center of members.
- Use rebar development length in cross section layout as per the BDS.

Loads

Figure 1-1 in Section 1.10.8.3 illustrates typical forces acting on a box culvert (three-sided frame shown, but similar). Each load acting on the culvert is discussed in greater detail below.

- Dead Loads – Dead loads include the self-weight of the structure. Do not include headwall and parapet loads in this analysis.
- Earth Pressure Loads – Refer to the MBE for the modified general load rating equation that includes the EV, EH, ES, and LS loads for culverts. BRASS is not capable of accounting for the appropriate factors for EV, EH, ES, and LS loads; therefore, these loads shall be entered into BRASS as DW loads with the appropriate correction factor. Table 1-2 in Section 1.10.8.3 summarizes these correction factors.

  Earth pressure may reduce the effects of other loads and forces on the structure. BRASS accounts for these reduced effects with the minimum and maximum load factors for DW.

  For the earth pressure calculations, apply maximum fill depth and pavement heights. If the structure does not rate, apply the average fill and pavement depths.

EV - Vertical Pressure from Dead Load of Earth Fill

- Assume unit weight of 120 pcf, unless otherwise documented

EH - Horizontal Earth Pressure Load

- Assume unit weight of 120 pcf, unless otherwise documented.
- Use at rest earth pressure coefficient, k_0 = 1-sinϕ'_f. Use ϕ'_f = 30˚ (k_0 = 0.5) unless soil testing has been performed.
- Apply as linearly distributed load.

ES - Earth Surcharge

- Represents a constant lateral earth pressure from fill above the top slab of the culvert.

LS - Live Load Surcharge

- Apply as *uniformly* distributed load on the retained soil

Live Loads

Live loads shall be applied to the structure as specified in BDS – *Distribution of Wheel Load through Earth Fills.*

Design Load - Design Load Ratings shall be calculated for the HL-93 Truck and Tandem without lane load, HS20 Truck, and HS20 lane. Design Loads shall be analyzed for single loaded lane and include the single lane multiple presence factor.

Legal Load - Legal Loads shall be analyzed for single loaded lane, however the 1.2 single-lane multiple presence factor shall not be applied to this loading.

Permit Load - Permit Loads shall be analyzed for single loaded lane, however the 1.2 single-lane multiple presence factor shall not be applied to this loading.

Dynamic Load Allowance – For the live load and impact calculation, apply minimum fill depth and pavement heights. If the culvert does not rate, apply the average fill and pavement depths. Dynamic load allowance is not considered for culverts with > 8’ of fill (i.e., 0% Dynamic Impact).

Live Load Distribution through Fill: Refer to the BDS for guidance on distribution of fill and live load distribution factors. When fill is > 2’, live loads are approximated as equivalent discreet point loads calculated by spreadsheet or other method and the multiple presence factor of 1.2 shall be included only for Design Loads. Consult with the LRE for single-span culverts with fill depth > 8’ and span lengths exceeding the fill depth and for multi-span culverts where the depth of fill exceeds the distance between faces of end walls. The vertical live load should be applied as a moving load across the top of the culvert structure.

Limit States

For the design loads and legal loads, the culvert should be load rated for the *Strength I* limit state. For permit loads, the culvert should be load rated for the *Strength II* limit state. Refer to the MBE *Limit States and Load Factors for Load Rating Table*.

Load Effects

Culvert structural members should be evaluated for flexure, shear, and axial thrust. Load ratings at several critical sections for the culvert must be calculated for each load effect to establish the lowest load rating.

- **Moment –** If a haunch exists and negative moment controls the load rating, then the negative moment shall be checked at the intersection of the haunch and the uniform depth member.
- **Shear –** Shear should be evaluated at the critical section, where d_v is the greater of 0.9d and 0.72h, where d is the distance from top of slab to the center of the bottom matt of rebar and h is the depth of the slab. If a haunch exists, the critical section is taken at $0.5d_v$ from the face of the change in slab thickness (the intersection of the haunch and the uniform depth member). If no haunch exists, the critical section is taken at d_v from the face of wall. Consider the general procedure (MCFT) initially, including the longitudinal reinforcement check. Otherwise, the simplified procedure may be used for depths 16.0 inches or less.
- **Axial Thrust –** If the axial demand is lower than 10 percent of factored nominal compressive strength then factored bending moment load can be checked for factored flexural resistance without considering the axial-flexural interaction.

Load Factors

Load factors shall be determined in accordance with section 1.10.4.3 of this manual. A Legal Load Factor of 2.0 specified as the MBE for Box Culverts shall be applied.

1.10.8.5 Reinforced Concrete Culvert Rating Spreadsheet

If the BRASS load rating for a frame/slab culvert that meets the general rebar cross-section/layout as shown in Figure 1-2 below requires posting for any of the legal load vehicles, then the Reinforced Concrete (R/C) Frame Culvert Rating Spreadsheet shall be used. Generally, rebars Asw-/Ass- and Ass+ alternate every other rebar spacing in these types of structures.

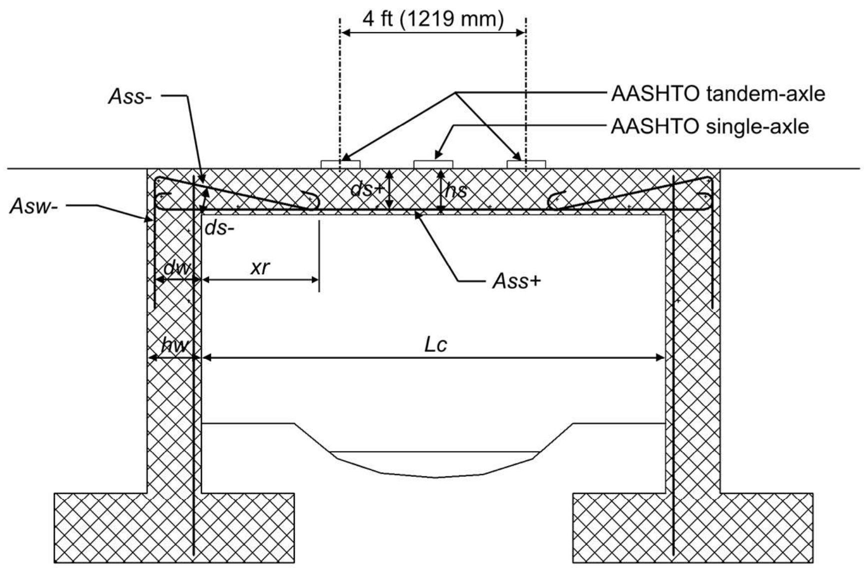


Figure 1-2 Concrete Moment Frame Culvert

This spreadsheet program was created to address structures that have reinforcing extending from the slab down into the culvert walls with insufficient length to be considered as a true frame culvert but does transfer partial load from the slab to the walls unlike a true slab. The spreadsheet program is good for structures meeting the general configuration of the schematic above and that has a span length in the 10'-16' range and fill depth less than 2'. For structures with fill depths greater than or equal to 2', consult LRE for guidance and obtaining the spreadsheet. The program was created by the University of Delaware as part of the 2014 research project titled "*System Capacity of Vintage Reinforced Concrete Moment Frame Culverts*." The user is required to input bridge information in the yellow highlighted fields in the "Input" tab of the spreadsheet. For additional details and information regarding this research project and for an explanation of the spreadsheet program, please refer to the final research report.

1.10.8.6 Arch Bridge Structures

This section outlines the methodology for load rating arch bridges. Below is guidance which specifically applies to these analyses.

The approach outlined below for load rating arch bridges is expected to yield conservative rating factors. More precise load ratings factors may be produced by utilizing more refined methods, such as actual live load distribution, soil-structure interaction, and the contribution of spandrel walls to stiffness and strength.

Bridge Model/Configuration

The following guidance shall be used when modeling an arch bridge:

The arch bridge should be modeled using enough elements so that the results are valid. The number of elements required for modeling an arch bridge can vary depending upon the degree of curvature of the arch. One way to validate the model is to make sure two successive models generate very close output. For example, if the LR creates an 8-element and a 10-element model and the results are significantly different the LR should consider adding more elements. If the LR then creates a 12-element model in which the results are similar to the 10-element model, then the results for the 10-element model are validated and are acceptable for the load rating.

The soil-structure interaction (i.e., using springs) doesn't need to be considered. This will create a conservative rating.

Loads

- Dead Loads- The fill depth for each element should be calculated taking the average fill depth at the two end nodes.
- Live Loads – The live load shall be positioned in the model to maximize live load effects. To determine critical locations, generate an influence diagram for unit point loads at various points along the span. For arch bridges with greater than 2' fill, refer to BDS *Distribution of Wheel Load through Earth Fills*. When the arch is under fill, the live load for each element is different. The depth of the fill for each element can be calculated using the average of the depths of the two nodal points of the element.
- Dynamic Load Allowance - Loading shall include impact through fill as per AASHTO. When the arch is under fill, the dynamic impact for each element is different. The depth of the fill for each element can be calculated using the average of the depths of the two nodal points of the element.
- Earth Pressure Loads – Backfill shall be modeled as a variable distributed load along the arch. Lateral earth pressure shall be applied as a linearly varying load.
- Combined Axial & Flexure - The combined effect of axial force and bending moment shall be considered using the methods outlined in the MBE.

1.10.9 Steel Bridge Load Ratings

The information below is supplemental to the general load rating procedure as it specifically applies to steel structures. Refer to Section 1.10 of this Manual for guidance on section properties, material properties, load factors, and general load rating procedures.

1.10.9.1 Longitudinal Steel Girder Bridges

This section outlines the methodology for load rating longitudinal steel girders. Below is guidance which specifically applies to these analyses.

Bridge Model/Configuration

The following guidance shall be used when modeling a longitudinal steel girder bridge:

- For concrete encased beams, assume composite action between the deck and beam if the concrete encasement is in good condition. Assume the concrete encasement below the deck soffit is dead load and does not provide additional structural capacity.
- Bearing stiffeners shall be included in the load rating for all longitudinal steel girders. If the rating for a rolled beam is controlled by the bearing stiffener and the requirements of BDS *D6.5 Concentrated Loads Applied to Webs Without Bearing Stiffeners*, then the bearings stiffeners can be neglected. The *Rolled Beam Without Bearing Stiffeners Spreadsheet* may be used to check this criterion. Bearing stiffeners shall be included in the load rating analysis beams when BDS D6.5 is *not* met and for plate girders.
- When limited information regarding the steel section is provided on plans, field measurements should be used to determine the steel section that most closely matches the field conditions to be used for the load rating. Refer to historical beam charts to determine the steel section properties.
- Refer to section 1.10.9.4 of this Manual for additional guidance regarding horizontally curved multi-beam bridges.

Loads

- Dead Loads
  - Diaphragms for non-horizontally curved bridges are assumed to not provide any structural capacity and should be treated as dead load calculation for the rating. Refer to section 1.10.9.4 for diaphragms on horizontally curved bridges.
  - Splice plates are assumed to be adequate to maintain continuity between adjoining beam members. The splice plate material shall be included in the dead load calculations for the rating. If the LR sees evidence of section loss on splice plates that may affect the load capacity of the bridge load rating, contact the LRE for additional guidance.
  - Transverse and Longitudinal Stiffeners need to be accounted for in the dead load calculations for the rating. This is accomplished through the creation of point or uniform loads.
  - All concrete encasement for beams below what is being considered as the structural deck, shall be treated as additional dead load applied to the beams.

Limit States

Fatigue Limit State does not need to be checked.

1.10.9.2 Girder-Floorbeam-Stringer Bridges

This section outlines the methodology for load rating girder-floorbeam-stringer bridges. Below is guidance which specifically applies to these analyses.

Girders and stringers shall be load rated in accordance with Section 1.10.9.2. For load rating floorbeams, see the following guidance.

Loads

- Live Loads – Live load shall be distributed longitudinally to the floorbeam using the lever rule.
- Dynamic Load Allowance - Floorbeams at the cantilevered end of a bascule bridge span shall have the dynamic impact doubled as per the guidance in the BDS.

1.10.9.3 Truss Bridges

This section outlines the methodology for load rating truss bridges. Below is guidance which specifically applies to these analyses.

Bridge Model/Configuration

The following guidance shall be used when modeling a truss bridge:

- Bottom and top chord components shall be broken up into individual elements between node points. For continuous portions of top & bottom chords, evaluation of moment in the continuous portion of the chord member should be considered.
- Gusset plate analysis shall be included in accordance with the MBE.
- Prior to load rating main truss gusset connections, a field inspection should be conducted to determine the presence of localized and/or uniform corrosion. If section loss due to corrosion exists at locations which coincide with the failure planes, the resistance of gusset plate may be reduced. Refer to the MBE for additional guidance.

1.10.9.4 Curved Girder Bridges

This section outlines the methodology for load rating curved girder bridges. Below is guidance which specifically applies to these analyses.

Bridge Model/Configuration

The following guidance shall be used when modeling a curved girder bridge:

- Refer to the current edition of *AASHTO Guide Specifications for Horizontally Curved Steel Girder Highway Bridges with Design Examples for I-Girder and Box-Girder Bridges* for analysis of curved girders.

- Bridges that contain both straight and horizontally-curved segments shall be analyzed as horizontally curved bridges.
- Diaphragms and cross-frame members shall be considered primary members and should be load rated.
- The effects of curvatures may be ignored in the determination of major-axis bending moments in horizontally curved steel I- and box-girder bridges provided the conditions of BDS 4.6.1.2.4b and 4.6.1.2.4c, respectively, are satisfied.

1.10.9.5 Steel Bridge Connections

This section outlines the methodology for load rating steel bridge connections. Below is guidance which specifically applies to these analyses.

Except for gusset plate connections, typical connections are assumed to have adequate capacity and do not control the load rating, unless there is evidence of advanced deterioration.

1.10.10 Timber Bridge Load Ratings

The information below is supplemental to the general load rating procedure as it specifically applies to timber structures. Refer to Section 1.10 of this Manual for guidance on section properties, material properties, load factors, and general load rating procedures.

Materials

The following guidance shall be used when modeling a timber bridge:

Reference design values from the BDS and appropriate adjustment factors shall be applied. Refer to existing plans for material properties. If plans are not available, assume Southern Yellow Pine Grade No. 1 Dense for nail laminated slabs and timber stringer bridges. For glulam deck panels, assume Southern Yellow Pine with a minimum unadjusted bending stress of 2,400 psi.

Dynamic Load Allowance – Dynamic load allowance does not apply to timber structures as per the BDS.

1.10.10.1 Timber Stringer Bridges

This section outlines the methodology for load rating timber stringer bridges. Below is guidance which specifically applies to these analyses.

Bridge Model/Configuration

The following guidance shall be used when modeling a timber stringer bridge:

Loads

- Dead Loads - For timber beam bridges with timber deck planking, the weight of bridge railing and curbs shall be distributed along the exterior beams only.

Condition Factor ϕ_c – In the case of deck planking, only the superstructure rating shall be considered when selecting the appropriate Condition Factor.

1.10.10.2 Glulam and Nail Laminated Timber Slab Bridges

This section outlines the methodology for load rating glulam and nail laminated timber slab bridges. Below is guidance which specifically applies to these analyses.

Bridge Model/Configuration

The following guidance shall be used when modeling a glulam or nail laminated timber slab bridge:

Glulam panel slabs can be assumed to act together when transverse timber spreader beams or transverse post tensioning rods are used.

Loads

- **Dead Loads -** The weight of the railing, curbs, and asphalt shall be uniformly distributed over the width of the timber slab bridge.

  Spreader beams and connections shall be included as dead loads.

1.10.11 Pipe Culvert Load Ratings

This section serves to describe DelDOT's load rating procedures for pipe culvert bridge structures as part of its Bridge Inspection and Load Rating Programs. These procedures fulfill the requirements of NBIS regarding the National Bridge Program Metrics, specifically Metric #13 *Inspection Procedures – Load Rating*.

The information below is supplemental to the general load rating procedure as it specifically applies to pipe culverts. Refer to Section 1.10 of this Manual for guidance on section properties, material properties, load factors, and general load rating procedures.

Information Gathering

The LR shall collect all necessary information for the pipe culvert to be load rated meeting the requirements of this document. The data may come from manufacturer's documentation, bridge design plans, DelDOT Standard Specs, and field collected data. The data should be included and documented on the Pipe Culvert Load Rating Summary Form (see Figure 1-3). In addition, the RF & Posting Summary Form (Section 1.11 Figure 1-7) and the Posting Weight Summary Form (Section 1.11 Figure 1-8) shall be included, if applicable.

If the bridge inspector performs the data collection required for the load rating evaluation, then the Pipe Culvert Load Rating Summary Form shall be submitted to DelDOT's LRE for review and completion of the load rating evaluation and documentation. The LRE may assign review responsibility to other qualified DelDOT load rating staff as needed.

DelDOT Pipe Culvert Load Rating Summary Form

Bridge Number:	**2191 000**
Structure Information (Field Collected):	
Structure Material (e.g. concrete, etc)	RCP
Number of Pipes	3
Size of Pipes (inches):	60
Average Spacing Between Pipes (ft):	3
Depth of Fill Over Pipes *(under travel lanes) (ft):	5
Metal Pipe Corrugation Spacing (in):	N/A
Metal Pipe Corrugation Depth (in):	N/A
Metal Pipe Thickness / Gauge (in):	N/A
Notes:	
* Taken from top of roadway to top of pipe	
Structure Information:	
Year Constructed:	2006
Concrete Pipe Type:	Class III
Metal Pipe Type:	N/A
Notes:	
Load Rating Evaluation Method:	**Design Table Based Evaluation**
Design Resource:	**American Concrete Pipe Association**
Load Rating Assumptions:	**A Type II pipe installation**
Load Rating Results (for HL-93/HS20):	**Pass**
Design Load Inventory Rating (tons):	**36**
Design Load Operating Rating (tons):	**60**
Posting information:	
Posting Requirements:	None
Posting Resolutions:	N/A
Load Rating Company:	DelDOT
Bridge Inspection Team Leader:	N/A
Load Rater:	Shelby Caballero
Load Rating Engineer:	Ping Jiang, P.E.
Load Rating Review:	Jason Arndt, P.E.
Load Rating Date:	5/20/2016
Comments:	

Figure 1-3 DelDOT Pipe Culvert Load Rating Summary Form

Load Rating Methods

LRFR ratings for pipe culverts that are in fair-new condition may be based on the pipe manufacturer's documentation of the design capacity, provided that the following documentation is available. Sufficient documentation shall be included to confirm that the pipe culvert has been designed for the HL-93 Design Load, and as-built conditions are within the manufacturer's recommendation (i.e., cover requirements, backfill requirements). If the pipe culvert does *not* meet all the above criteria, an LRFR rating shall be performed for the pipe culvert, based on the design requirements of the BDS. Additionally, the loads and factors shall be computed in accordance with the BDS.

The BMS has identified multiple evaluation options for the load rating assignment of pipe culvert bridge structures. This includes reinforced concrete, metal, and high-density polyethylene (HDPE) pipes. The different evaluation methods account for new design/construction, existing pipe culverts, and condition-based evaluations.

Pipe Culvert Load Rating Methods

There are several methods for load rating pipe culverts, which are discussed in detail below. Figure 1-4 is a table outlines criterion for selection of a load rating method.

Preferred Pipe Culvert Load Rating Method Selection

Load Rating Method	NBI Culvert Condition Rating		
	Metal	R/C	HDPE
Design Table Based	≥ 5	≥ 5	≥ 5
Condition Based	≤ 4 or Does not Meet Design Table Requirements	≥ 5 and Does Not Meet Requirements of Design Tables	
Analytical	N/A*	≤ 4	≤ 4

* Condition Method is preferred, but Analytical Method may be used in specific circumstances as determind by LRE or BME

Figure 1-4 Preferred Pipe Culvert Load Rating Method Selection Table

- Design Table Based Evaluation – This evaluation is based on the methodologies presented by the appropriate pipe association design manual (typically through design tables) and is considered a pre-designed type of evaluation. This means that the pipe culverts have been designed to carry the HL-93/HS20 loadings and, if the bridge being evaluated meets specified criteria, the pipe is adequate for the design loads.

  Pipe culvert bridges successfully meeting design table requirements shall have the inventory and operating rating factors of 1.0 and 1.67, respectively, assigned. This correlates to an inventory rating weight of 36 tons and an operating rating weight of 60 tons for the HS20/HL-93 design vehicle. If the load rating for the HL-93/HS20 is greater than or equal to 1.0, the Delaware Legal Load Vehicles do not need to be considered because the design loads are intended to encompass all legal loads. The legal load rating shall be entered as the gross vehicle weight of the respective vehicle. Examples of the Design Table Based Evaluation method for metal, concrete, and HDPE pipe culverts can be found in Appendix 1-4, 1-5, and 1-6, respectively.

If a pipe culvert bridge does not successfully meet the design table or condition requirements, either the Condition or Analytical Based Evaluation method shall be utilized.

- Analytical Based Evaluation – Another option for evaluating the load rating for pipe culvert bridges consists of performing a structural analysis. This can be accomplished via commercial analytical software or spreadsheet-based programs. The structural analysis will provide a more detailed evaluation of the bridge structure and may result in improved load rating factors for the design and legal load vehicles.

  A spreadsheet based analytical program has been created for metal pipe culverts and shall be used when an analytical based evaluation is required for DelDOT owned pipe culvert bridges. This spreadsheet is available upon request. Currently, DelDOT does not have appropriate structural analysis software for the load rating evaluation of concrete and HDPE pipe culvert bridge structures. Therefore, Bridge Inspection or Bridge Design Consultants may be utilized for performing the analysis, if applicable.

  The specific Design and Legal Load rating factors or weights determined through an analytical evaluation shall be used when reporting load rating data in the NBI and within the bridge inspection file.

- Condition Based Evaluation – Pipe culvert bridges with a NBI culvert condition rating of 4 or less, or which do not meet the requirement of design tables may have their load ratings determined by an assessment of the deterioration of the culvert material and loss of surrounding soil. Refer to the BEIM for further discussion and policy requirements regarding metal pipe culvert bridges. For concrete and HDPE culverts that have an NBI condition rating of 4 or less, consult the LRE or BME to discuss analytical and posting requirements.

  Pipe culvert bridges with a NBI culvert condition rating of 4 or higher that are load rated by the Condition Based Evaluation method shall have the HS20/HL-93 inventory and operating ratings assigned as shown in Figure 1-5. If the inventory load rating for the HL-93/HS20 is 36 tons, the Delaware Legal Load Vehicles do not need to be considered because the design loads are intended to encompass all legal loads. The legal load rating shall be entered as the gross vehicle weight of the respective vehicle.

  Pipe culvert bridges with a NBI culvert condition rating of 3 or lower that are load rated by the Condition Based Evaluation method shall have the HS20/HL-93 inventory and operating ratings assigned as shown in Figure 1-5. For metal pipe culverts the HS20/HL-93 rating shall also be used for the Delaware Legal Loads, as the inspection criteria will result in a gross vehicle weight load posting that will be applied to all loads. For concrete or HDPE culverts the rating shall be based on analysis or assessment as approved by the LRE or BME.

NBI Design Load Rating Data

NBI Culvert Condition Rating	Design Rating (tons)	Pipe Culvert Type		
		Metal	R/C	HDPE
≥ 5	Inventory	36		
	Operating	60		
= 4	Inventory	36*		
	Operating	36*		
= 3	Inventory	15	As per the analysis results	
	Operating	15		
= 2	Inventory	3		
	Operating	3		
< 2	Inventory	'0' and Bridge Shall Be Closed		
	Operating			

* Regarding R/C & HDPE Bridges, this is only applicable once the analysis has been completed and the results show that the bridge does not require posting for legal loads.

Figure 1-5 NBI Design Load Rating Data

Loads

Design Load - The goal in using any, or combination of, the evaluation methodologies identified in this section, is to confirm that a bridge can safely carry the design load vehicle(s) as identified in the MBE. It is assumed that the design loads encompass the Delaware, SHV, and emergency vehicle legal loads. Therefore, if the evaluation results in the bridge to "Pass" for the design vehicle(s), then the load rating evaluation process is complete and can be finalized. For a bridge to "Pass" for the design load vehicle(s), one of the following is required to occur:

- Obtaining certain data through use of the construction plans and/or field verification to confirm that required parameters have been met as per the design tables and charts within the appropriate design manual – *Design Table Based Evaluation.*
- Performing a structural analysis and confirming that the calculated rating factor for the design and legal vehicle(s) ≥ 1.0 – *Analytical Based Evaluation Method*
- The NBI culvert condition rating for a pipe culvert bridge is a 5 or higher – *Condition Based Evaluation Method*

Legal Load – Regardless of if the requirements identified in the corresponding design manual and associated tables are met when the NBI culvert condition rating for a concrete or HDPE pipe culvert is a 4 or less, a structural analysis including evaluation of the Delaware, Specialized Hauling, and the FHWA Emergency Legal Vehicles shall be considered to verify if the bridge needs to be posted. Whether or not an analytical evaluation is performed may be dependent on the type of deterioration or defect warranting the bridge to be classified as Structurally Deficient. An example of this might include an RCP bridge that has excessive joint separation because of poor backfill and compaction techniques, but the concrete is not showing any signs of deterioration.

Documentation – All load rating data, assumptions, calculations, manual excerpts, and software outputs shall be saved and stored as part of the finalized load rating document. The Pipe Culvert Load Rating Summary Form (Figure 1-3) shall be included for NBI pipe culvert bridges but is not required for non-NBI bridges unless an analytical evaluation was conducted.

Copies of appropriate tables, charts, or documentation from the corresponding design manual, along with any DelDOT specification excerpts, shall be included with the finalized load rating when the Design Table Based Evaluation Method is used.

A paper copy of the finalized load rating document shall be printed and placed in the “active” bridge inspection file. In addition, an electronic copy (PDF) of the load rating document shall be stored in the live database as well as on the appropriate DelDOT network. The DelDOT Pipe Culvert Load Rating Summary and Posting Weight Summary forms shall be included when the Analytical Based Evaluation Method is used. A sample of this form can be found in Figures 1-3 and 1-8. Other examples of the required documentation can be found in Appendix 1-4, 1-5, and 1-6.

Once the LR and LRE sign off on the Pipe Culvert Load Rating Summary Form, all documentation shall be provided to the BME so the database and inspection file can be updated accordingly and, if necessary, the load posting resolution can be processed. When updating the database and the NBI data fields related to the load ratings, the LRFR rating method shall be selected for Manufacturer, Design Table and Analytical Based Evaluation methods. Similarly, the field evaluation/judgement rating method shall be selected for a Condition Based Evaluation for assigning the load rating.

Proper Coding of the Design Load NBI Item (#31) data field shall adhere to the following protocol:

- Condition Based Evaluations for all material types; 5: HS 20
- Design Table Based Evaluation: Concrete = A: HL93 / HDPE = 9: HS 25 / Metal = 5: HS20

Analytical Based Evaluations:

- Load Resistance and Factor Design; A: HL 93
- Load Factor or Allowable Stress Design; 5: HS20 / 9: HS 25

Proper coding of the Inventory and Operating Rating Type NBI item (#64 & #66) data fields shall adhere to the following protocol:

- “0”: Engineering Judgement/Evaluation for Condition Based Evaluation Method
- “8”: LRFR for Analytical Based Evaluation Method
- “1”: LFR for Analytical Based Evaluation Method
- “0”: LRFR for Manufacturer’s Documentation or Design Table Based Evaluation (all material types)

1.10.12 Bridges with No Plans

The information below is supplemental to the general load rating procedure as it specifically applies to bridges with no plans. Refer to Section 1.10 of this Manual for guidance on section properties, material properties, load factors, and general load rating procedures.

This guidance serves to describe DelDOT’s load rating procedures for bridge structures that do not have design/construction plans as part of its Bridge Inspection and Load Rating Program. These procedures fulfill the requirements of NBIS regarding the National Bridge Program Metrics, specifically Metric #13 – Inspection Procedures – Load Rating.

All bridges without plans are required to have a load rating as per the procedures outlined in this Manual. If a bridge without plans does not have an existing load rating or if the existing load rating is not properly documented, it shall be completed during the next routine inspection by DelDOT load rating staff. This document is applicable to bridges meeting the NBI requirement as well as non-NBI pipe culvert bridge structures; however, some of the evaluation methodologies discussed below only pertain to NBI bridges.

DelDOT’s BMS has identified multiple evaluation options for the load rating assignment of existing structures that do not have plans available. The different evaluation methods include condition-based assessments, field measurements, and load testing activities. Each method is discussed in more detail below. Once a thorough search for plans has been completed and no documentation is found, one method or a combination of these evaluation methods shall be utilized for determination of appropriate load rating data.

Load Rating Methods

- Field Measurement Based Evaluation – This method utilizes field measured superstructure and deck geometries to complete a traditional load rating analysis using structural analysis software. The preferred software is BRASS, but other software may be used provided it has been approved by the LRE. In addition to field measurements, this method may also include material properties identified from material testing procedures, such as concrete coring, pachometer or steel couponing if deemed necessary. Bridges of similar construction and age that have plans may be used as a guide with the approval of the LRE. Older DelDOT Specifications may be referenced as well for selecting material properties. Otherwise, the material properties called out in the MBE shall be used.

When conducting a Field Measurement Based Analysis, all measurements and data obtained out in the field shall be sketched up and stored with the load rating documentation and within the inspection file.

This evaluation method can be utilized for NBI and non-NBI bridge structures. The load rating shall include the HL-93/HS20 design vehicles and the Delaware Legal and Permit Vehicles as part of the analysis. Essentially, the standard load rating protocol that is described in this Manual shall be followed. The structural analysis will provide a more detailed evaluation of the bridge structure and may result in improved load rating factors for the design and legal load vehicles.

- **Condition Based Evaluation** – This method is the primary method for identifying the load rating for all bridge structures without plans that have a minimum NBI Condition Rating of 5 or higher, regardless of material type. Depending on the specific type of structure, it may not be necessary to include consideration of the NBI Substructure Condition Rating for meeting the requirement for use of this method. Factors to take into consideration when selecting this evaluation method should include the age of the bridge, detour length, ADT, and comparison of similar bridge structures that have plans and a structural analysis completed.

  Bridges evaluated using this method shall have the inventory and operating rating factors for the design vehicle of 1.0 and 1.67 assigned, respectively. This correlates to an inventory rating weight of 36 tons and an operating rating weight of 60 tons for the HS20 design vehicle.

- **Load Test Based Evaluation** – This evaluation method utilizes in-service load testing for determining bridge element stresses for back calculation of acceptable load rating analysis. This method may be necessary when the minimum NBI Condition Rating for a particular bridge becomes structurally deficient (condition rating $\leq$ 4). It may also be used if the structural analysis determined through the Field Measurement Based Evaluation method results in the bridge requiring posting. Load testing will need to be accomplished using Bridge Inspection or Bridge Design Consultants, or in collaboration with the University of Delaware. Coordination with DelDOT District personnel will be needed for scheduling of loaded dump trucks necessary for the load testing. Decision to utilize this method will be discussed between the LRE and the BME.

Loads

Design Load - The goal in using any, or combination of, the evaluation methodologies identified in this section, is to confirm that a bridge can safely carry the design load vehicle(s) as identified in the MBE. It is assumed that the design loads encompass the Delaware, SHV, and emergency vehicle legal loads. Therefore, if the evaluation results in the bridge to “Pass” for the design vehicle(s), then the load rating evaluation process is complete and can be finalized. For a bridge to "Pass" for the design load vehicle(s), one of the following is required to occur:

- Performing a structural analysis utilizing field measured data and confirming that the calculated rating factor for the design and legal vehicle(s) $\geq$ 1.0 – *Field Measurement Based Evaluation Method.*
- The NBI Culvert Condition Rating for a bridge without plans is a 5 or higher – *Condition Based Evaluation Method.*
- Performing a structural analysis utilizing load testing data and confirming that the calculated rating factor for the design and legal vehicle(s) $\geq$ 1.0 – *Load Test Based Evaluation Method.*

Otherwise, the bridge will require posting. Refer to Section 2 of this Manual for additional information about bridge posting.

Documentation – All load rating data, assumptions, calculations, manual excerpts, and software output shall be saved and stored as part of the finalized load rating document. The Load Rating Summary Form shall be included for NBI bridges but is not required for non-NBI bridges unless a structural analysis utilizing a Field Measurement or Load Test Based Evaluation was conducted. Refer to Section 1.11 Figure 1-6 for an example of the Delaware Bridge Load Rating Summary Form.

All documentation from the DelDOT specification excerpts shall be included with the finalized load rating, if applicable.

A paper copy of the finalized load rating document shall be printed and placed in the "active" bridge inspection file. In addition, an electronic copy (PDF) of the load rating document shall be stored in the live database as well as on the appropriate DelDOT network. The RF & Posting Summary Form (Figure 1-7) and Posting Weight Summary Form (Figure 1-8) forms shall be included when the Field Measurement or Load Test Based Evaluation method is used.

Once the LR / Bridge Inspector and LRE signs off on the Load Rating Summary form, all documentation shall be provided to the BME so the database and inspection file can be updated accordingly and, if necessary, the Load Posting Resolution can be processed. When updating the database and the NBI data fields related to load ratings, the LRFR rating method shall be selected for Field Measurement and Load Test Based Evaluation methods. Similarly, the field evaluation/judgement rating method shall be selected for a Condition Based Evaluation for assigning the load rating. Proper coding of the Design Load NBI item (#31) data field shall adhere to the following protocol, unless other documentation states otherwise:

- Year built for bridge is < 1959; 4: H 20
- Year built for bridge is > 1958 and < 1996; 5: HS 20
- Year built for bridge is > 1995; A: HL 93

Proper coding of the Inventory and Operating Rating Type NBI item (#64 & #66) data fields shall adhere to the following protocol:

- “0” Engineering Judgement/Evaluation for Condition Based Evaluation Method
- “8” LRFR for Field Measurement Based Evaluation Method
- “4” Load Test for Load Test Based Evaluation

1.11 Load Rating Report

When ratings are performed, a Load Rating Report shall be submitted to the LRE. The Load Rating Report shall include the following:

1. Electronic copy of the Delaware Bridge Load Rating Summary Form, including material properties (documented, assumed, and/or measured), structural analysis and loading assumptions, file names, posting requirements, load rating comments, and load rating date, and signatures of rater and reviewer (see Figure 1-6).
2. Electronic copy of the RF & Posting Summary Form, including identification of controlling output file and the rating factors for all design, legal, and permit loads (see Figure 1-7).
3. Electronic copy of the Posting Weight Summary Form, including the identification of the controlling output file and the Posting Weights for the legal loads (see Figure 1-8).
4. Electronic copies of data file(s).
5. Electronic copies of output summary file(s) for all design, legal, and permit load ratings.
6. Plans or sketches showing all properties and assumptions, as necessary.
7. Documentation of structural model used in analysis, if other than BRASS, where appropriate.

Upon finalizing the Load Rating Report, the BME updates the load rating data in BrM and stores the Load Rating Report on the network and a hard copy in the bridge inspection file.

The following NBI Fields must be updated on the BrM Inspection / Appraisal page:

- Item 31 – Design Load
- Item 41 – Structure Open, Posted, or Closed to Traffic
- Item 63 – Operating Rating Method
- Item 64 – Operating Rating
- Item 65 – Inventory Rating Method
- Item 64 – Inventory Rating
- Item 70 * – Bridge Posting
- Rating Date
- Initials (Load Rater)

* Use Legal Load with highest percentage reduction of legal load

The following DelDOT Agency Fields must be updated on the Inspection / DelDOT Load Ratings page if bridge posting is required:

- Reason for Posting
- Date of Resolution
- S220 Posting Load
- S335 Posting Load
- S437 Posting Load
- T330 Posting Load
- T435 Posting Load
- T540 Posting Load
- SU4 Posting Load
- SU5 Posting Load
- SU6 Posting Load
- SU7 Posting Load
- EV2 Posting Load
- EV3 Posting Load

When ratings are performed in conjunction with the preparation of design drawings, the LRE will provide a Load Rating Summary Table (see Figure 1-9) for inclusion in the General Plan.

Delaware Bridge Load Rating Summary Form

Bridge Number:	2223A223
Structure Information:	
Structure Type (e.g., Rigid Frame, etc.)	1 Simply Supported Box Girder Prestressed Concrete (Pretensioned Strands)
Structure Material Properties (e.g., Steel Yield Strength, Concrete breaking strength, etc.)	Prestressed Beams: f'c = 5.0 ksi, f'ci = 4.0 ksi Parapet f'c = 4.0 ksi Rebar: Fy = 60 ksi Prestressing: Grade 270
Source of Structure Information:	
Design Contract numbers and date	Contract # 83-072-03
Others (e.g. AASHTO manual, field data report, etc.)	
Load Rating Methods and Assumptions:	**LRFR**
Analysis and Modeling Assumptions	
Rating Method (e.g. Hand calculation, Software used, etc.)	BRASS Girder
Load Rating Results:	
Load Rating Input File Names[1]:	2-223A_Ext_G1.DAT
	2-223A_Int_G2.DAT
Load Rating Output File Names:	2-223A_Ext_G1.OUT
	2-223A_Int_G2.OUT
Critical Element Output File Name:	See **RF Posting Weights Summary Form**
Others (e.g. Load rating report, Contr. #) [2]:	
Posting information:	
Posting Requirements:	None
Posting Resolutions:	
Load Rating Company:	Delaware DOT
Load Rating Engineer:	Raymond Eskaros
Review (must be a PE):	Ping Jiang
Load Rating Date:	7/11/2018
Comments:	The exterior girder is in control for all trucks, but under normal operating conditions the exterior girder is partially covered by the parapet which means that it will bear only 1 wheel of any truck, so I considered that in my rating by changing the Scale Factor.

Note 1: Load rating input files should be fully documented including load rating assumptions, analysis model, load distribution, etc.
Note 2: If the load rating is performed by contractors, load rating reports should be fully documented including all assumptions, analysis model, load distribution, etc. duing load rating analysis.

Figure 1-6 Delaware Bridge Load Rating Summary Form

Rating Factor Summary Form

Bridge:	2223A223
Date:	7/11/2018

Design Vehicle	Weight (tons)	Rating Factor	Rating Weight (tons)	Controlling File
HL-93 Truck + HL-93 Lane (Inventory)	36	1.22	43.94	2-223A_Int_G2.OUT
HL-93 Tandem + HL-93 Lane (Inventory)	25	1.26	31.60	2-223A_Int_G2.OUT
HS20 (Inventory)	36	1.51	54.20	2-223A_Int_G2.OUT
HL-93 Truck + HL-93 Lane (Operating)	36	1.58	56.97	2-223A_Int_G2.OUT
HL-93 Tandem + HL-93 Lane (Operating)	25	1.64	40.97	2-223A_Int_G2.OUT
HS20 (Operating)	36	1.95	70.25	2-223A_Int_G2.OUT
LANEHS20	36	2.89	104.20	2-223A_Int_G2.OUT
Legal Vehicle	Weight (tons)			Controlling File
DE S220	20	2.31	46.13	2-223A_Int_G2.OUT
DE S335	35	1.25	43.69	2-223A_Int_G2.OUT
DE S437	36.64	1.19	43.44	2-223A_Int_G2.OUT
DE T330	30	2.19	65.68	2-223A_Int_G2.OUT
DE T435	35	1.83	63.92	2-223A_Int_G2.OUT
DE T540	40	1.68	67.39	**2-223A_Ext_G1.OUT**
EV2	28.75	1.80	51.63	**2-223A_Ext_G1.OUT**
EV3	43	1.16	49.83	2-223A_Int_G2.OUT
SU4	27	1.62	43.67	2-223A_Int_G2.OUT
SU5	31	1.50	46.64	2-223A_Int_G2.OUT
SU6	34.75	1.35	47.03	2-223A_Int_G2.OUT
SU7	38.75	1.26	48.73	2-223A_Int_G2.OUT
Emergency/Bus Vehicle	Weight (tons)			Controlling File
B216	15.5	3.27	50.62	2-223A_Int_G2.OUT
B218	18.1	2.77	50.12	2-223A_Int_G2.OUT
FE46	22.9	2.19	50.24	2-223A_Int_G2.OUT
FR50	24.9	1.96	48.78	2-223A_Int_G2.OUT
FE54	26.9	2.00	53.70	2-223A_Int_G2.OUT
FL77	38.4	1.29	49.57	2-223A_Int_G2.OUT
Permit Vehicle	Weight (tons)			Controlling File
AC2	28	2.49	69.71	2-223A_Int_G2.OUT
AC3	42	1.61	67.51	2-223A_Int_G2.OUT
AC4	56	1.42	79.59	2-223A_Int_G2.OUT
AC5	60	1.36	81.63	2-223A_Int_G2.OUT

Rating & Posting Weights for legal loads are based on MBE (2nd Edition, 2011 w/ 2013 Interim revisions).

Rating factors for AC2 through AC5 trucks are for Bridge Management use/reference only.

(blue)	= Fields that are to be entered by the Load Rater
(orange)	= Field that is to be enetered by the Load Rater. What is being entered is the controlling HL93 load configuration. This is to account for bridge configurations that require additional HL93 load configurations be evaluated for. As an example, the load rating for a two-span continuous bridge less than 200' in length would include, both, the HL93 truck & lane load and the HL93 truck & Truck Train & Lane load. If the controlling load was the HL93 truck & truck train & lane load, then the Load Rater would enter "HL-93-TRKTRA Inv" instead of the "HL-93 Truck Inv".

Figure 1-7 RF & Posting Summary Form

Posting Weight Summary Form

Bridge	2223A223
Date	7/11/2018

Legal Vehicle	Weight (tons)	Rating Factor	Posting Weight (tons)	Controlling File
DE S220	20	2.31	**N/A**	2-223A_Int_G2.OUT
DE S335	35	1.25	**N/A**	2-223A_Int_G2.OUT
DE S437	36.64	1.19	**N/A**	2-223A_Int_G2.OUT
DE T330	30	2.19	**N/A**	2-223A_Int_G2.OUT
DE T435	35	1.83	**N/A**	2-223A_Int_G2.OUT
DE T540	40	1.68	**N/A**	2-223A_Ext_G1.OUT
EV2	28.75	1.80	**N/A**	2-223A_Ext_G1.OUT
EV3	43	1.16	**N/A**	2-223A_Int_G2.OUT
SU4	27	1.62	**N/A**	2-223A_Int_G2.OUT
SU5	31	1.50	**N/A**	2-223A_Int_G2.OUT
SU6	34.75	1.35	**N/A**	2-223A_Int_G2.OUT
SU7	38.75	1.26	**N/A**	2-223A_Int_G2.OUT

= Signifies that the bridge needs to posted for this vehicle

Figure 1-8 Post Weight Summary Form

Load Rating Summary Table					
Vehicle Type	Rating Factor	Rating Weight (tons)	Controlling Member	Controlling Point	Load Effect
HL-93 Truck (Inventory)	1.14	N/A	Span 1: Interior Beam	109.59	Strength I
HL-93 Tandem (Inventory)	0.87	N/A	Span 1: Interior Beam	105	Strength I
HS20 (Inventory)	1.14	41.04	Span 1: Interior Beam	109.59	Strength I
HL-93 Truck (Operating)	1.48	N/A	Span 1: Interior Beam	109.59	Strength I
HL-93 Tandem (Operating)	1.13	N/A	Span 1: Interior Beam	105	Strength I
HS20 (Operating)	1.48	53.28	Span 1: Interior Beam	109.59	Strength I
DE S220	2.19	43.80	Span 1: Interior Beam	106	Strength I
DE S335	0.90	31.50	Span 1: Interior Beam	105	Strength I
DE S437	1.05	38.85	Span 1: Interior Beam	105	Strength I
DE T330	2.08	62.40	Span 1: Interior Beam	105	Strength I
DE T435	1.46	51.10	Span 1: Interior Beam	105	Strength I
DE T540	1.45	58.00	Span 1: Interior Beam	105	Strength I
EV2	1.49	42.84	Span 1: Interior Beam	105	Strength I
EV3	0.96	41.28	Span 1: Interior Beam	105	Strength I
SU4	1.45	39.15	Span 1: Interior Beam	105	Strength I
SU5	1.35	41.85	Span 1: Interior Beam	105	Strength I
SU6	1.26	43.79	Span 1: Interior Beam	105	Strength I
SU7	1.26	48.83	Span 1: Interior Beam	105	Strength I

Figure 1-9 Load Rating Summary Table

1.12 References

Concrete Pipe Culvert Design Manual, 2011 Edition
American Concrete Pipe Association
2011 Publication

Corrugated Polyethylene Pipe Design Manual & Installation Guide
Plastic Pipe Institute

Corrugated Steel Pipe Design Manual, 2nd Edition
National Corrugated Steel Pipe Association

DelDOT Bridge Design Manual, 2019 Edition
Delaware Department of Transportation
2019 Publication

DelDOT Bridge Element Inspection Manual
Delaware Department of Transportation
2017 Publication

DelDOT Bridge Inspection Manual
Delaware Department of Transportation
2017 Publication

Effective Width of Concrete Slab Bridges in Delaware
University of Delaware, Department of Civil & Environmental Engineering
2012 Publication

Load Rating of Arch Bridges, M. Chajes
Delaware Center for Transportation, University of Delaware
2002 Publication

LRFD Bridge Design Specifications, 9th Edition
American Association of State Highway and Transportation Officials (AASHTO)
2020 Publication

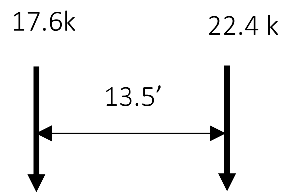
LRFD Fill Height Tables for Concrete, 2017 Edition
American Concrete Pipe Association
2017 Publication

Manual for Bridge Evaluation, 3rd Edition
American Association of State Highway and Transportation Officials (AASHTO)
2018 Publication

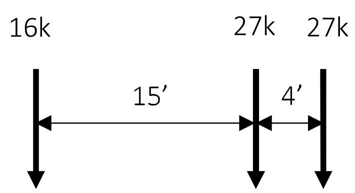
System Capacity of Vintage Reinforced Concrete Moment Frame Culverts
University of Delaware, Department of Civil & Environmental Engineering
2014 Publication

Appendix 1-1 Delaware Legal Load Axle Configurations

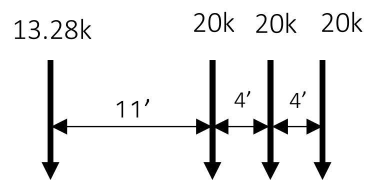
S220 – 20 Ton - DE 2 Axle Single Unit



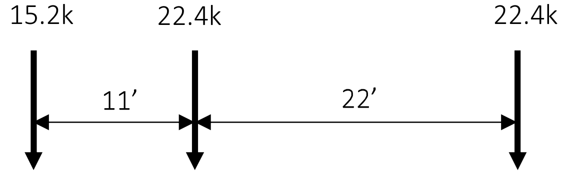
S335 – 35 Ton – DE 3 Axle Single Unit



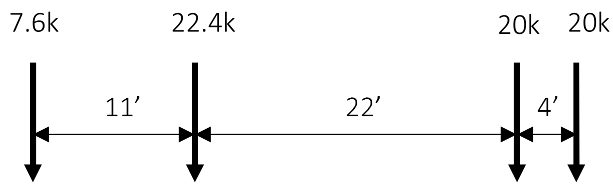
S437 – 37 Ton – DE 4 Axle Single Unit



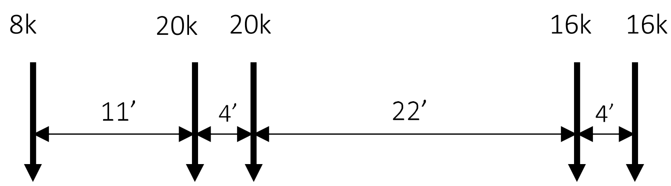
T330 – 30 Ton – DE 3 Axle Semi



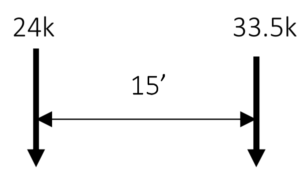
T435 – 35 Ton – DE 4 Axle Semi



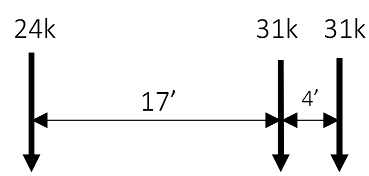
T540 – 40 Ton – DE 5 Axle Semi



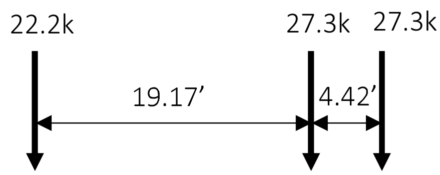
EV2 – 28.75 ton – Single Rear Axle Emergency Vehicles



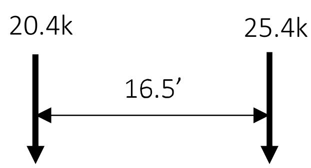
EV3 – 43 ton – Tandem Rear Axle Emergency Vehicles



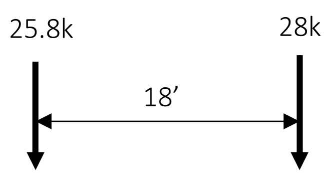
FL77 (3 Axle Ladder Truck) 38.4 Ton



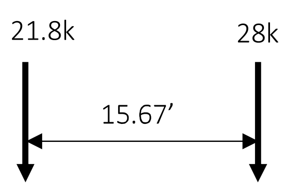
FE46 (2 Axle Small Engine/Pumper Truck) 22.9 Ton



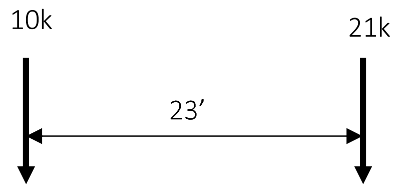
FE54 (2 Axle Large Engine/Pumper Truck) 26.9 Ton



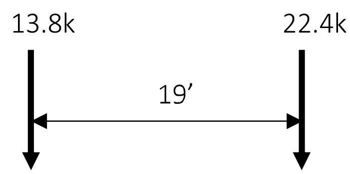
FR50 (2 Axle Rescue/Medic Truck) 24.9 Ton



B216 (2 Axle School Bus) 15.5 Ton

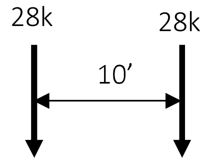


B218 (2 Axle Dart Bus) 18.1 Ton

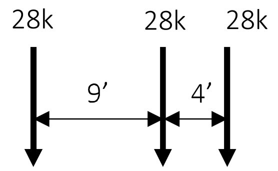


Appendix 1-2 Delaware Permit Load Axle Configurations

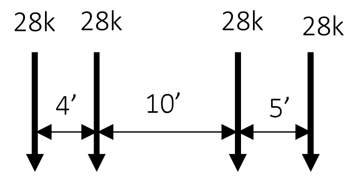
AC2 – 2 Axle Annual Permit Crane



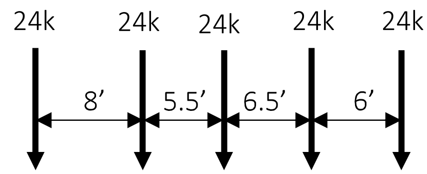
AC3 – 3 Axle Annual Permit Crane



AC4 – 4 Axle Annual Permit Crane



AC5 – 5 Axle Annual Permit Crane



Appendix 1-3 Legal Live Load Factors for Fast Act Emergency Vehicles

NCHRP Project 20-07/Task 410

EV Frequency	Traffic Volume (One Direction)	Live Load Distribution	EV2	EV3
10 EV crossings per day	ADTT < 1,000 free flowing	Two or more lanes DF	1.10	1.10
	ADTT > 6,000 free flowing		1.40	1.10
	ADTT > 6,000 congested		1.50	1.20
10 EV crossings per day	ADTT < 1,000 free flowing	From Refined Analysis	1.20	1.15
	ADTT > 6,000 free flowing		1.50	1.35
	ADTT > 6,000 congested		1.65	1.45
1 EV crossing per day	ADTT < 1,000 free flowing	Two or more lanes DF	1.10	1.10
	ADTT > 6,000 free flowing		1.20	1.10
	ADTT > 6,000 congested		1.30	1.10
1 EV crossing per day	ADTT < 1,000 free flowing	From Refined Analysis	1.20	1.10
	ADTT > 6,000 free flowing		1.30	1.20
	ADTT > 6,000 congested		1.45	1.30

Appendix 1-4 CMP Design Table Evaluation Example

Below is an example of a load rating summary form completed for a steel CMP culvert. The information, tables, and figures provided in this appendix are independent of the BLRM and serve as supplemental material to provide guidance on this topic.

DelDOT Pipe Culvert Load Rating Summary Form

Bridge Number:	**2371A371**
Structure Information (Field Collected):	
Structure Material (e.g. concrete, etc):	Steel CMP
Number of Pipes:	3
Size of Pipes (inches):	137 x 87
Average Spacing Between Pipes (ft):	4.583
Depth of Fill Over Pipes *(under travel lanes) (ft):	3.0 min / 3.25 max / 3.125 average
Corrugation Spacing (in):	5
Corrugation Depth (in):	1
Metal Pipe Thickness / Gauge (in):	0.109
Notes:	**Min. Depth of fill over pipes excluding the asphalt roadway thickness is 2.4' (~29")**
* Taken from top of roadway to top of pipe	
Structure Information:	
Year Constructed:	2015
Concrete Pipe Type:	N/A
Metal Pipe Type:	Type III
Notes:	
Load Rating Evaluation Method:	**Design Table Based Evaluation**
Design Resource:	**National Corrugated Steel Pipe Association**
Load Rating Assumptions:	
Load Rating Results (for HL-93/HS20):	**Pass**
Design Load Inventory Rating (tons):	**36**
Design Load Operating Rating (tons):	**60**
Posting information:	
Posting Requirements:	None
Posting Resolutions:	N/A
Load Rating Company:	DelDOT
Bridge Inspection Team Leader:	N/A
Load Rater:	Jason Arndt,P.E.
Load Rating Engineer:	Ping Jiang,P.E.
Load Rating Date:	10/29/2015
Comments:	**Depth of fill material under travel lanes used for analysis (not including asphalt or any base course):** - Min = 1.75' - Max = 2.0' - Average = 1.875' **Depth of base courses and asphalt = 1.25'** **Depth of Asphalt = 0.6'**

7. Longitudinal Seam Strength:
   SS = Cx2 = 26,220x2 = 52,440 lb/ft required
   From Table 7.4A, the seam strength for 0.170 thickness = 81,000 lbs/ft
   52,400 < 81,000 **OK**

   Note: A thinner wall would meet this requirement but design is controlled by the flexibility factor limit, step 6.

8. Footing Reaction
   Weight of soil on arch = [(rise + H) span – flow area]
   = [(9.83 + 19.0) 23 - 171]120 = 59,050 lb/ft.
   R_{dl} = Vertical reaction @ spring line due to soil load
   = Weight of soil/2 = 29,525 lbs/ft
   R_{ll} = Vertical reaction @ spring line due to live load
   Assume two trucks meeting.
   R_{ll} = 64,000/(8 + 2H) = 64,000/{8+[2(19 + 9.83)} = 975 lbs/ft
   $R_{total} = R_{dl} + R_{ll}$ = 29,525 + 975 = 30,500 lbs/ft
   R_v = vertical footing reaction = R cos(α)
   = 30,500 cos(14.09) = 29,580 lbs/ft
   R_h = Horizontal footing reaction = R sin(α)
   = 30,500 sin(14.09) = 7,425 lbs/ft.

Results: For the 6 x 2 inch corrugation, a specified wall min. thickness of 0.170 inchwith standard seams (2 bolts/corrugation or 4 bolts/ft) is an acceptable design. The footings must be designed for R_v = 29,583 lbs/ft and R_h = 7,425 lbs/ft.

HEIGHT OF COVER TABLES FOR STANDARD CORRUGATED STEEL PIPE

The following height-of-cover tables are presented for the designer's convenience to use in routine applications. They are based on the design procedures presented in this chapter for the AISI method. The following values were adopted:

Unit weight of soil = 120 pcf
Density of compacted backfill = 90% AASHTO T-99
AISI load reduction factor K = 0.86

Fill heights for factory made pipe are based on helical seam fabrication. Joint strength must be checked for factory made pipe with other types of seams.

Except as noted, embankment or trench construction is permitted.

The live load pressure from other concentrated loads is often calculated on the basis of a load distribution slope of 1/2 to 1 (horizontal to vertical). A method is also provided in the AASHTO *LRFD Bridge Design Specifications*.

Minimum Covers

Minimum covers for H20 and H25 highway loads are taken as the greater of span/8 or 12 inches for all corrugated steel pipe except spiral rib pipe. For spiral rib pipe, this becomes span/4, but not less than 12 inches. In all cases, the minimum cover is measured from the top (inside rise) of the pipe to the bottom of the asphalt pavement course and to the top of rigid pavements.

While asphalt does at least as good a job of distributing wheel loads as soil, it is not counted in the minimum cover. The asphalt layer is often very thick and must be placed and compacted in lifts with heavy equipment which would then be on the pipe with inadequate cover. Considering the asphalt thickness as part of the minimum cover could lead to construction problems.

Minimum covers for E 80 railroad loads are twice those for H20 and H25 highway loads, except for structural plate structures. Because of its deeper corrugations and greater bending strength, minimum cover is taken as span/5 or 24 inches, whichever is greater. E 80 minimum covers are measured from the top (inside rise) of the corrugated steel structure to the bottom of the tie.

Guidelines for minimum covers for construction loads are shown in Table 7.8. In some cases the minimum cover provided for design live loads may not be sufficient for the heavier loads from construction equipment. In such cases the construction contractor must provide any additional cover required to avoid damage to the pipe.

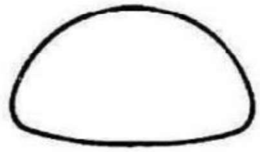
Table 7.8

General guidelines for minimum cover required for heavy off-road construction equipment

Pipe Span, in.	Minimum Cover (ft) for Indicted Axle Loads (kips)*			
	18-50	50-75	75-110	110-150
12-42	2.0	2.5	3.0	3.0
48-72	3.0	3.0	3.5	4.0
78-120	3.0	3.5	4.0	4.0
126-144	3.5	4.0	4.5	4.5

* Minimum cover may vary, depending on local conditions. The contractor must provide the additional cover required to avoid damage to the pipe. Minimum cover is measured from the top of the pipe to the top of the maintained construction roadway surface.

The significance of aircraft loads is principally in the area of required minimum cover. Airplanes weighing up to 1-1/4 million pounds and using tire pressures of 225 psi have been used to develop minimum cover tables for the Federal Aviation Administration. See Tables AISI-24 through AISI-27.



AISI-11

Height-of-Cover Limits for Corrugated Steel Pipe Arch
H20 or H25 Live Load • 5 x 1 in. and 3 x 1 in. Corrugations

Span & Rise in.	Minimum Specified Thickness Required 3 x 1 in.	Minimum Specified Thickness Required 5 x 1** in.	Minimum* Cover in.	Maximum Cover (ft) Over Pipe Arch for Soil Corner Bearing Capacity of 2 tons/ft²
53 x 41	0.079	0.109	12	25
60 x 46	0.079	0.109	15	25
66 x 51	0.079	0.109	15	25
73 x 55	0.079	0.109	18	24
81 x59	0.079	0.109	18	21
87 x 63	0.079	0.109	18	20
95 x 67	0.079	0.109	18	20
103 x 71	0.079	0.109	18	20
112 x 75	0.079	0.109	21	20
117 x 79	0.109	0.109	21	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
137 x 87	0.109	0.109	24	19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
150 x 96	0.138	0.138	30	19
157 x 101	0.138	0.138	30	19
164 x 105	0.138	0.138	30	19
171 x 110	0.138	0.138	30	19

Notes:
1. Soil bearing capacity refers to the soil in the region of the pipe corners. See Chapter 10 for design of pipe envelope at pipe corners. The remaining backfill around the pipe arch must be compacted to a specified AASHTO T-99 density of 90%
2. Use reasonable care in handling and installation.
3. Pipe arches are typically used where the cover does not exceed 15 feet.

* Minimum covers are for H20 and H25 loads. See Table 10.1 for construction load requirements. Minimum covers are measured from top of pipe to bottom of flexible pave-ment or top of pipe to top of rigid pavement. Minimum cover must be maintained in unpaved traffic areas.

** Same thicknesses as specified for 3 x 1 may be provided when the corner radius meets the requirements of ASTM A760.

Since the minimum depth of fill over the pipes, excluding the asphalt thicknesses, is 28.75" (2.7') which is greater than the 24" minimum highlighted above – the bridge "Passes" for the design vehicles.

Appendix 1-5 Concrete Pipe Culvert Design Table Evaluation Example

Below is an example of a load rating summary form completed for a concrete pipe culvert. The information, tables, and figures provided in this appendix are independent of the BLRM and serve as supplemental material to provide guidance on this topic.

DelDOT Pipe Culvert Load Rating Summary Form

Bridge Number:	**2166B166**
Structure Information (Field Collected):	
Structure Material (e.g. concrete, etc):	RCP
Number of Pipes:	3
Size of Pipes (inches):	1 -72" & 2- 60"
Average Spacing Between Pipes (ft):	3
Depth of Fill Over Pipes *(under travel lanes) (ft):	2.67 min / 2.9 max / 2.8 average
Corrugation Spacing (in):	N/A
Corrugation Depth (in):	N/A
Metal Pipe Thickness / Gauge (in):	N/A
Notes:	**Min. Depth of fill over pipes excluding the asphalt roadway thickness is 2.0' (24")**
* Taken from top of roadway to top of pipe	
Structure Information:	
Year Constructed:	2012
Concrete Pipe Type:	Class III
Metal Pipe Type:	N/A
Notes:	Pipes are in fairly new condition
Load Rating Evaluation Method:	**Design Table Based Evaluation**
Design Resource:	**American Concrete Pipe Association**
Load Rating Assumptions:	**A Type II pipe installation**
Load Rating Results (for HL-93/HS20):	**Pass**
Design Load Inventory Rating (tons):	**36**
Design Load Operating Rating (tons):	**60**
Posting information:	
Posting Requirements:	None
Posting Resolutions:	N/A
Load Rating Company:	DelDOT
Bridge Inspection Team Leader:	N/A
Load Rater:	Jason Arndt,P.E.
Load Rating Engineer:	Ping Jiang,P.E.
Load Rating Date:	12/23/2015
Comments:	**Depth of fill material under travel lanes used for analysis (not including asphalt or any base course):**
	- Min = 1.35' - Max = 1.56' - Average = 1.455' **Depth of base courses and asphalt = 1.34'** **Depth of Asphalt = 0.67'**

611.13 Basis of Payment. The quantity of brick masonry will be paid for at the Contract per square foot (square meter). Price and payment will constitute full compensation for excavating and backfilling; for furnishing and placing all materials; for the disposal of surplus materials; and for all labor, equipment, tools, and incidentals required to complete the work, including cleaning.

SECTION 612 – REINFORCED CONCRETE PIPE

612.01 Description. This work consists of furnishing and installing reinforced concrete round or elliptical pipe. This work also includes the construction of connections to existing drainage inlets and manholes as may be required to complete the work.

MATERIALS.

612.02 Reinforced Concrete Pipe.

(a) *Round Pipe.* Reinforced concrete round pipe shall conform to the requirements of AASHTO M170 (M 170M) and shall be Class III unless otherwise noted.

(b) *Elliptical Pipe.* Pipe designed for placement with the major axis horizontal shall be designated as horizontal elliptical pipe (HE). Pipe designed for placement with the major axis vertical shall be designated as vertical elliptical pipe (VE).

Reinforced concrete elliptical pipe shall conform to the requirements of AASHTO M207 (M 207M) and the following:

(1) Standard strength reinforcement concrete elliptical pipe (HE or VE) shall be Class III.
(2) Extra strength reinforced concrete elliptical pipe (HE or VE) shall be Class IV.

No pipe shall be shipped from the plant to the Project until the requirements of AASHTO M170 (M 170M) or M207 (M 207M) are met and the pipe is marked with the Department's inspection stamp. The manufacturer shall have clearly marked on the pipe the following information before inspection is made:

(1) Pipe class
(2) Pipe type, HE or VE, for elliptical pipe only
(3) Date of manufacture
(4) Name or trademark of the manufacturer
(5) One end of each section of elliptical pipe shall be clearly marked, during the process of manufacture or immediately thereafter, on the inside and the outside of the opposite walls along the minor axis.

All pipe inspected and approved at the manufacturing plant shall be subject to inspection at the site of the work, and no previous stamp or approval shall bar rejection if the pipe is found to be defective or damaged.

612.03 Joint Material. A rubber gasket conforming to the requirements of AASHTO M 315 (M 315 M) shall be used to seal the joints between successive sections of pipe.

612.04 Backfill Material. Backfill material shall conform to the requirements of Subsection 209.04, Borrow Type C. If the existing material meets these requirements, it shall be used for pipe backfill.

Engineer.

207.03 Excavation. Excavation shall be sufficient in volume to place the full widths, thicknesses, and lengths of footings. Undercutting of edges, ends, corners, and other surfaces will not be permitted. If a sump area is required to keep the excavation dry during construction, it shall be outside the footing line.

All suitable materials removed during excavation shall be used, as far as practicable, in the formation of roadway embankments, or as structure backfill if it meets the requirements of Subsection 207.05. No excavated material shall be wasted without permission. Boulders, logs, structure remnants, or other obstructions shall be considered unsuitable materials. All unsuitable and excess material shall be disposed of as specified in Subsection 106.09, or as directed.

When the excavation is completed, the Engineer will make an inspection of the footing area. No concrete shall be placed until the depth and character of the foundation material are approved.

207.04 Cofferdams. All sheeting and bracing shall be carried to sufficient depth to obtain, as nearly as possible, a watertight cofferdam. The cofferdam shall have ample clearance to allow inspection of the forms for the finished structure and to provide sump areas. The forms for concrete shall not be braced against the cofferdam, unless approved.

Cofferdams shall be constructed to protect new concrete against damage from flooding. Cofferdams shall be dewatered in a manner that prevents the loss of concrete materials.

Unless otherwise approved, cofferdams and cribs, including all sheeting and bracing, shall be removed by the Contractor after the completion of the substructure. No timber shall remain in finished concrete structures. Care shall be taken to avoid disturbing or damaging the finished structure during removal operations.

The Contractor shall submit detailed layout, working drawings, and calculations sealed by a Professional Engineer registered in Delaware, showing the proposed method of cofferdam construction. These drawings shall be approved before cofferdam construction begins. Approval of the Contractor's drawings will not relieve the Contractor of any responsibility for the adequacy and safety of the cofferdam construction.

207.05 Backfilling. All backfilling of structures shall conform to the requirements of Subsection 202.05 (c), (d), and (e). Unless otherwise specified, all backfilling around and over structures shall be performed with material conforming to the requirements of Subsection 209.04, Borrow Type C. Backfill material shall be compacted to 95% or more of the maximum density according to the requirements of Subsection 202.05 (f). When backfilling next to bridges, culverts, or other structures, no heavy mechanical compacting equipment will be permitted over the structure until a minimum of 18" (450 mm) of cover has been placed.

Backfill adjacent to rigid frames, arches, timber structures, and other similar structures shall be brought up simultaneously at each abutment, so that no unbalanced stresses are introduced.

207.06 Method of Measurement. The quantity of excavation and backfilling for structures, excluding rock excavation, will be measured in cubic yards (cubic meters) based on field measurements. The volume will be computed by taking the difference in elevation between the existing ground surface, or the bottom of roadway excavation, or the bottom of channel excavation, whichever is lower, and the surface of the completed structure excavation at plan grade or at an approved revised plan grade.

Volume measurements will include, between the upper and lower limits defined above, the volume contained inside vertical planes located 18" (450 mm) outside of the neat line perimeter of the compensation for excavating suitable and unsuitable material from the trench within the limits specified; for hauling, storing, and final disposal of excavated material; for placing and compacting backfill; for placing sheeting and shoring; for constructing cribs; for dewatering; and all labor, equipment, tools, and incidentals required to complete the work.

Additional trench excavation, directed by the Engineer to establish the foundation below the elevation indicated on the Plans, will be paid for on the basis of the Contract unit price per cubic yard (cubic meter) plus an additional percentage corresponding to the total depth lowered, as indicated in Table 207-A. The Contract unit price plus the additional percentage shown in Table 207-A shall be accepted by the Contractor as full compensation as defined in this Subsection for excavating to depths below those designated on the Plans.

Rock excavation will be paid for under Section 206.

Borrow for backfill will be paid for under Section 210.

SECTION 209 – BORROW

209.01 Description. This work consists of furnishing and placing additional material from approved borrow areas or other approved sources when suitable material available within the right-of-way is not sufficient in quantity for construction purposes. This work also includes all clearing, grubbing, or stripping required to prepare the borrow area for cross-sectioning and excavating.

MATERIALS.

209.02 General Requirements. The uses, classifications, characteristics, and definitions of terms for borrow materials shall be in accordance with the requirements of AASHTO M 57, Modified; M 145, Modified; and M 146 and M 147, Modified.

Unless otherwise directed, all materials having the following properties shall be excluded from use:

(a) Material with a maximum dry weight less than 90lb/ft^3 (1440 kg/m^3).

(b) Material with a liquid limit greater than 50.

(c) Material containing frozen material, rubbish, boulders in excess of 6" (150 mm) in any direction, or organic matter such as leaves, roots, grass, or sewage.

209.03 Materials Testing. The method of testing materials shall be in accordance with the requirements of AASHTO T 88, Modified; T 89, Modified; T 90, Modified; and T 99 Method C, Modified.

209.04 Borrow Types. The following types of borrow are subject to the requirements of this Section.

(a) *Borrow Type A.* This material shall have between 95 and 100% inclusive, by dry weight, passing a 2½" (63 mm) sieve and a maximum of 35%, by dry weight, passing a No. 200 (75 µm) sieve.

(b) *Borrow Type B (Special Fill).* This material shall have 100%, by dry weight, passing a 3" (75 mm) sieve and a maximum of 10%, by dry weight, passing a No. 200 (75 µm) sieve.

(c) *Borrow Type C (Backfill).* This material shall have between 85 and 100% inclusive, by dry weight, passing a 1" (25.0 mm) sieve and a maximum of 25%, by dry weight, passing a No. 200 (75 µm) sieve.

3

Table 1: Standard Installation Soils and Minimum Compaction Requirements

Installation Type	Bedding Thickness	Haunch and Outer Bedding	Lower Side
Type 1	D_o/24 minimum, not less than 3" (75 mm) If rock foundation, use D_o/12 minimum, not less than 6" (150 mm)	95% Category I	90% Category I, 95% Category II, or 100% Category III
Type 2	D_o/24 minimum, not less than 3" (75 mm) If rock foundation, use D_o/12 minimum, not less than 6" (150 mm)	90% Category I or 95% Category II	85% Category I, 90% Category II, or 95% Category III
Type 3	D_o/24 minimum, not less than 3" (75 mm) If rock foundation, use D_o/12 minimum, not less than 6" (150 mm)	85% Category I, 90% Category II, or 95% Category III	85% Category I, 90% Category II, or 95% Category III
Type 4	No bedding required except if rock foundation, use D_o/12 minimum, not less than 6" (150 mm)	No compaction required, except if Category III, use 85%	No compaction required, except if Category III, use 85%

Reference: ASCE 15-98, "Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)", 1998.

Table 3: Reinforced Pipe Classes for 0.01 inch Crack Per ASTM C 76 (lbs/ft/ft)

Class I	≤ 800
Class II	≤ 1000
Class III	≤ 1350
Class IV	≤ 2000
Class V	≤ 3000
Special Design	> 3000

Table 2: Equivalent USCS and AASHTO Soil Classifications for Standard Installation Soil Designations

Representative Soil Types			Percent Compaction	
SIDD	USCS	AASHTO	Standard Proctor	Modified Proctor
Gravelly Sand (Category I)	SW, SP, GW, GP	A1, A3	100 95 90 85 80 61	95 90 85 80 75 59
Sandy Silt (Category II)	GM, SM, ML, Also GC, SC with less than 20% passing #200 sieve	A2, A4	100 95 90 85 80 49	95 90 85 80 75 46
Silty Clay (Category III)	CL, MH, GC, SC	A5, A6	100 95 90 85 80 45	90 85 80 75 70 40
Not Allowed for Haunch or Bedding	CH	A7	100 95 90 45	90 85 80 40

Reference: ASCE 15-98, "Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)", 1998.

NOTES:
1. Compaction and soil symbols – i.e. "95% Category I" refers to Category I soil material with a minimum Standard Proctor compaction of 95%. See Table 2 for equivalent Modified Proctor values.
2. Soil in the outer bedding, haunch, and lower side zones shall be compacted to at least the same compaction as the majority of soil in the overfill zone.

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Fill Height Tables are based on:
1. γs = 120 pcf
2. AASHTO HL-93 live load
3. Positive Projecting Embankment Condition - this gives conservative results in comparison to trench conditions

D-Load (lb/ft/ft) for Type 2 Bedding

Class I, Class II, Class III, Class IV, Class V, Special Design

Pipe Size (in)	Fill Height in Feet													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
12	1492	1322	880	727	694	705	741	788	704	781	858	934	1011	1087
15	1434	1272	851	707	676	688	724	771	691	843	841	915	990	1065
18	1358	1240	834	697	668	680	717	763	688	837	835	909	983	1056
21	1220	1218	824	692	665	678	715	762	689	839	836	909	983	1056
24	1202	1203	818	690	665	680	717	764	694	844	841	915	988	1062
27	1151	1162	796	679	657	675	714	762	696	846	842	915	989	1062
30	1471	1213	823	701	674	690	727	773	699	850	845	919	992	1065
33	1347	1168	805	693	669	688	727	773	704	855	850	923	996	1069
36	1244	1137	789	687	665	687	728	775	710	861	856	929	1003	1076
42	1084	1059	759	673	659	685	726	773	715	867	861	933	1006	1079
48	966	935	732	663	655	684	726	774	722	874	867	940	1013	1085
54	923	899	712	655	654	685	728	777	731	884	876	948	1021	1094
60	948	875	696	650	654	688	731	781	740	894	885	958	1031	1103
66	906	855	687	646	655	691	736	787	750	906	896	969	1041	1114
72	850	837	679	643	658	696	741	793	761	918	907	980	1053	1126
78	802	820	672	642	660	697	744	796	768	925	913	986	1059	1131
84	763	805	665	641	661	700	747	799	775	932	920	993	1065	1138
90	730	791	660	641	664	703	750	803	863	940	927	999	1072	1144
96	703	756	655	642	666	706	754	807	867	948	934	1006	1078	1151
102	679	734	662	649	674	714	761	814	875	1019	941	1013	1086	1158
108	660	723	668	657	681	721	769	822	882	1027	949	1021	1093	1165
114	643	729	675	665	689	729	776	830	890	1036	1016	1028	1100	1172
120	629	734	682	670	697	737	784	837	898	1044	1024	1036	1108	1180
126	617	740	689	678	705	744	792	845	905	1053	1032	1097	1115	1187
132	607	745	691	686	712	752	800	853	913	1061	1039	1105	1171	1195
138	599	751	686	694	720	760	808	861	921	1070	1047	1112	1178	1203
144	592	757	692	701	728	768	816	869	929	1079	1055	1120	1186	1253

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Appendix 1-6 HDPE Pipe Culvert Design Table Evaluation Example

Below is an example of a load rating summary form completed for a HDPE pipe culvert. The information, tables, and figures provided in this appendix are independent of the BLRM and serve as supplemental material to provide guidance on this topic.

DelDOT Pipe Culvert Load Rating Summary Form

Bridge Number:	**2275C275**
Structure Information (Field Collected):	
Structure Material (e.g. concrete, etc):	HDPE
Number of Pipes:	3
Size of Pipes (inches):	60
Average Spacing Between Pipes (ft):	3
Depth of Fill Over Pipes *(under travel lanes) (ft):	4.34 min / 4.84 max / 4.59 average
Corrugation Spacing (in):	N/A
Corrugation Depth (in):	N/A
Metal Pipe Thickness / Gauge (in):	N/A
Notes:	**Min. Depth of fill over pipes excluding the asphalt roadway thickness is 3.67' (44")**
* Taken from top of roadway to top of pipe	
Structure Information:	
Year Constructed:	2010
Concrete Pipe Type:	N/A
Metal Pipe Type:	N/A
Notes:	Pipes are in fairly new condition
Load Rating Evaluation Method:	**Design Table Based Evaluation**
Design Resource:	**Plastic Pipe Institute**
Load Rating Assumptions:	**Class II soil type & 95% compaction was used**
Load Rating Results (for HL-93/HS20):	**Pass**
Design Load Inventory Rating (tons):	**36**
Design Load Operating Rating (tons):	**60**
Posting information:	
Posting Requirements:	None
Posting Resolutions:	N/A
Load Rating Company:	DelDOT
Bridge Inspection Team Leader:	N/A
Load Rater:	Jason Arndt,P.E.
Load Rating Engineer:	Ping Jiang,P.E.
Load Rating Date:	12/15/2015
Comments:	**Depth of fill material under travel lanes used for analysis (not including asphalt or any base course):** - Min = 3.0' - Max = 3.5' - Average = 3.75' **Depth of base courses and asphalt = 1.34'** **Depth of Asphalt = 0.67'**

Table 5-4

Note: Minimum covers presented here were calculated based on a minimum of 6 in. (0.15 m) of structural backfill material over the pipe crown with an additional layer of compacted native soil for a total cover as shown. In shallow trafficked installations, especially where pavement is involved, it may be best to use a good quality compacted material to grade, to prevent surface settlement and rutting.

Inside Diameter, ID in (mm)	Minimum Cover, H ft (m)
3 (75)	1 (0.3)
4 (100)	1 (0.3)
6 (150)	1 (0.3)
8 (200)	1 (0.3)
10 (250)	1 (0.3)
12 (300)	1 (0.3)
15 (375)	1 (0.3)

Inside Diameter, ID in (mm)	Minimum Cover, H ft (m)
18 (450)	1 (0.3)
21 (525)	1 (0.3)
24 (600)	1 (0.3)
30 (750)	1 (0.3)
36 (900)	1 (0.3)
42 (1050)	1 (0.3)
48 (1200)	1 (0.3)
54 (1350)	1.5 (0.5)
60 (1500)	1.5 (0.5)

Table 5-4: Minimum Cover Requirements for Corrugated Polyethylene Pipe

Based on Class III Backfill Compacted to 90% Standard Proctor Density and AASHTO HS-25 Load

Maximum Cover

The prism load was assumed in the design procedure, which results in very conservative maximum cover limits. Highway loads have negligible effect in deep burials, as shown in Table 5-3. Maximum cover limits for corrugated polyethylene pipe are shown in Table 5-5 for a variety of backfill conditions. This table was developed based on pipe properties from Table 5-1.

Table 5-5

	Class I		Class II				Class III		
Pipe Dia.	uncompacted	compacted	85%	90%	95%	100%	85%	90%	95%
4	17(ft)*	59(ft)	17(ft)	24(ft)	37(ft)	59(ft)	15(ft)	18(ft)	24(ft)
6	16	57	16	24	36	57	15	17	24
8	14	51	14	21	32	51	13	15	22
10	13	50	13	20	31	50	12	14	21
12	13	49	13	20	31	49	12	14	21
15	13	49	13	20	31	49	12	14	21
18	13	49	13	20	31	49	12	14	21
24	13	51	13	21	32	51	12	14	21
30	13	51	13	21	32	51	12	14	21
36	13	50	13	20	31	50	12	14	21
42	11	47	11	19	29	47	10	13	19
48	11	46	11	18	29	46	10	12	19
54	11	44	11	18	28	44	10	12	18
60	11	45	11	18	28	45	10	12	19

Note: Alternate backfill materials and compaction levels not shown in the table may also be acceptable. This is a general guideline based on Table 5-1. Contact the manufacturer for further detail. *All cover heights measured in feet.

Table 5-5: Maximum Cover Heights based on Table 5-1 Section Properties

CHAPTER 5: DESIGN METHODOLOGY

Since the minimum amount of fill over the pipes is 3.67', which exceeds the minimum required of 1.5' and less than the maximum of 28 at 95% compaction for the Class II soil type, the pipes successfully meet the design table requirements and therefore can safely carry design loads.

Appendix 1-7 BRASS-GIRDER User Guide

This Appendix give additional guidance to using the BRASS-GIRDER load rating software. Each data input tab in the BRASS-GIRDER GUI has a help button, which when selected will bring up that specific topic in the software's help file and can be used to provide more information about the input variables in that tab.

Additional helpful hints for using BRASS-GIRDER effectively are described below.

Administration

The administration tab should be filled accordingly:

Bridge ID	BR X-XXX
Title 1	Bridge carrying (Road name) over (crossing feature)
Title 2	(Existing plan contract numbers)
Date	(Date)
Agency	DelDOT
Designer/Rater	(LR Name)
Reviewer	(LRR Name)

Live Load > Definitions (LRFD)

Using the Live Load > Definition tab allows the user to define which Library Vehicles or Special Vehicles (as defined in the Special Vehicle tab) to use in the analysis. While defining these vehicles the "Type" and "Design/Rating Procedure" must be defined. It is important to understand the differences between these two input variables.

The vehicle "Type" is used to define the default live load combinations and associated combination factors. Correctly defining a vehicle's "Type" prevents the user from having to define Load Combinations in the General Combinations (LRFD) tab. The help file provides a helpful table to use when defining this variable.

Option	Description
Design Truck	Design truck with variable rear axle spacing to 30 ft (9 m) combined with first design lane load
Design Tandem	Design tandem combined with first design lane load
Design Lane	Design lane
Design Truck Train	Two design trucks, positioned for critical effect, with a minimum of 50 ft (15 m) between the lead axle of one truck and the rear axle of the other combined with first design lane load
Design Tandem Train	Two design tandems, positioned for critical effect, with a variable spacing from 26 ft (8 m) to 40 ft (12 m) combined with first design lane load
Fatigue Truck	Fatigue truck
Legal Truck	Legal truck combined with first legal lane load and applied to spans greater than 200 ft
Legal Lane	Legal lane
Legal Truck Train	Two legal trucks, positioned for critical effect, with a fixed distance of 30 ft (9 m) between the lead axle of one truck and the rear axle of the other combined with first legal lane load
Permit Truck	Permit truck combined with first permit lane load
Permit Lane	Permit lane
General Truck	General truck
General Lane	General lane

It is important to understand how BRASS-GIRDER assigns the load combinations based on the vehicle “Type” to ensure it is correctly applied to each specific situation. Below is a list of standard vehicles and their vehicle “Types” for a typical bridge configuration. The LR shall verify these definitions for their specific bridge configuration before using.

Typical Bridge Configuration:

Design Vehicles:

HL-93-Truck - Design Truck
HL-93-Tandem - Design Tandem
HL-93-Lane - Design Lane
HS20T - General Truck
LANEHS20 - General Lane

Legal Vehicles:

S220 - General Truck
S335 - General Truck
S437 - General Truck

T330	-	General Truck
T435	-	General Truck
T540	-	General Truck
SU4	-	General Truck
SU5	-	General Truck
SU6	-	General Truck
SU7	-	General Truck
EV2	-	General Truck
EV3	-	General Truck
FL77	-	General Truck
FE46	-	General Truck
FE54	-	General Truck
FR50	-	General Truck
B216	-	General Truck
B218	-	General Truck

Permit Vehicles:

AC2	-	Permit Truck
AC3	-	Permit Truck
AC4	-	Permit Truck
AC5	-	Permit Truck

Additional Vehicles for Negative Moment:

Design Vehicles:

HL-93 TRKTRA	-	Design Truck Train
HL-93 TANTRA	-	Design Tandem Train

Legal Vehicles:

S220	-	Legal Truck Train
S335	-	Legal Truck Train
S437	-	Legal Truck Train
T330	-	Legal Truck Train
T435	-	Legal Truck Train
T540	-	Legal Truck Train
SU4	-	Legal Truck Train
SU5	-	Legal Truck Train
SU6	-	Legal Truck Train
SU7	-	Legal Truck Train
EV2	-	Legal Truck Train
EV3	-	Legal Truck Train
FL77	-	Legal Truck Train
FE46	-	Legal Truck Train

FE54	-	Legal Truck Train
FR50	-	Legal Truck Train
B216	-	Legal Truck Train
B218	-	Legal Truck Train
Legal-Lane	-	Legal Lane

Permit Vehicles:

AC2	-	Permit Truck
AC3	-	Permit Truck
AC4	-	Permit Truck
AC5	-	Permit Truck
Permit-Lane	-	Permit Lane

Additional Vehicles for spans greater than 200 feet:

Legal Vehicles:

S220	-	Legal Truck
S335	-	Legal Truck
S437	-	Legal Truck
T330	-	Legal Truck
T435	-	Legal Truck
T540	-	Legal Truck
SU4	-	Legal Truck
SU5	-	Legal Truck
SU6	-	Legal Truck
SU7	-	Legal Truck
EV2	-	Legal Truck
EV3	-	Legal Truck
FL77	-	Legal Truck
FE46	-	Legal Truck
FE54	-	Legal Truck
FR50	-	Legal Truck
B216	-	Legal Truck
B218	-	Legal Truck
Legal-Lane	-	Legal Lane

Permit Vehicles:

AC2	-	Permit Truck
AC3	-	Permit Truck
AC4	-	Permit Truck
AC5	-	Permit Truck
Permit-Lane	-	Permit Lane

Although the different “Types” of vehicles include Design, Legal, and Permit Trucks; this variable does not affect the Load Factor to be used in the analysis. That is defined in the “Design/Rating Procedure variable”.

Frame Orientation

When using BRASS-GIRDER to analyze a frame structure it is important to understand the orientation of the members. When defining the legs BRASS-GIRDER considers the beginning or “left” end of all legs as being located at the level of the superstructure.

Take a three-sided frame culvert which is symmetric about the center as an example. Here, the top face of the left leg is on the interior of the culvert and the bottom face is on the soil side. Whereas the top face of the span member and right leg are both on the soil side and the bottom face is on the interior. In this case, the reinforcing of the two legs must be defined as opposite from each other, with the reinforcing nearest the soil at the bottom (row 1) for the left leg and at the top (row 5) for the right left. Likewise, the lateral soil pressure loads must be oppositely defined, with the load on the left leg being negative and the load on the right leg being positive.

Schedules

Using the Schedules tab in BRASS-GIRDER allows the user to quick define variables along the member such as bracing, stiffeners, stirrups, etc. However, it is important to understand how BRASS-GIRDER uses this information in its analysis to ensure accurate results. BRASS-GIRDER uses the schedule tab to define ranges, not discrete points.

Take, for example, a 50’ long steel girder with transverse stiffeners spaced at 6.25’ throughout. If the user uses the schedule tab to define a transverse stiffener range from 0’ to 50’ with a spacing of 6.25’, BRASS-GIRDER will NOT determine that there are 9 stiffeners with one at 0’, another at 6.25’, another at 13’, another at 19.25’, etc. What BRASS-GIRDER does do is determine which range each point of interest is in, then assign a transverse spacing according to what is defined in that range.

This has two important consequences. First is that BRASS-GIRDER does not determine how many transverse stiffeners are on the girder, so it cannot determine the weight of these stiffeners to automatically add to the dead load. The weight of ancillary components of the girder must be added manually. Second is that a range should be defined across the entire span. In this example, if the user defined the transverse stiffener range from 6.25’ to 43.75’ (rather than 0’ to 50’), BRASS-GIRDER would define the transverse spacing for any Point of Interest between 0 and 6.25’ or 43.75’ to 50’ as 0.

Section 2 – Bridge Load Posting

2.1 Introduction

This section provides general guidance and DelDOT specific procedures for bridge posting related activities. Refer to the MBE for additional information on bridge posting.

2.2 Application

Bridge posting is required when state or national legal loads exceed the load carrying capacity of the bridge. It is DelDOT's policy to restrict loads on bridges when the legal load rating factor drops below 1.0 for any of the Delaware Legal Loads, the AASHTO Single-Unit SHV's, or the FHWA Emergency legal load vehicles. The minimum posting allowed for Delaware bridges is 3 tons. A bridge that has been assessed as being incapable of carrying a minimum gross live load of 3 tons shall be closed to traffic.

2.3 Posting Responsibility

Bridge load posting/restriction responsibilities reside solely with the BME. The BME is required to perform QA on all load rating analyses that result in a bridge being posted or the removal or modification of an existing bridge posting. If a bridge is required to be restricted for load upon completion of the BME's QA of the load rating, then the BME will assemble the Load Posting Resolution and distribute amongst required internal DelDOT staff and outside agencies as denoted in Section 2.6 of this Manual. The BME is also responsible for tracking and confirming that posting signs were removed or the correct posting signs were installed as required in the proper locations.

In addition to DelDOT-owned bridges, Title 17, Chapter 5, Section 510 of the Delaware Code allows DelDOT to conduct investigations of the load-carrying capacity of any public or private bridge, causeway, viaduct, or other elevated structure which crosses any public highway regardless of the owner or the owners of said bridge, causeway, viaduct, or elevated structure and regardless of what government has jurisdiction over it. If DelDOT determines that a load-restriction posting is warranted for a bridge, the Owner will be notified of the recommendation to restrict loads on the bridge. If the Owner of the bridge fails to implement the recommended restriction, DelDOT will implement the load restriction in accordance with this Manual and the Delaware Code.

2.4 Load Posting Requirements

This section provides an overview of load posting requirements.

2.4.1 When to Post

Structural loadings are compared to structural capacities to analyze all superstructure components to identify the critical members and to determine the appropriate load rating. Refer to Section 1 of this Manual for load rating policies and procedures. This may lead to load restrictions on the bridge or identification of components that require rehabilitation or other modification to avoid posting the bridge.

Corrugated metal pipe culverts may also require posting based on their inspected condition. DelDOT has created a *Corrugated Metal Culvert Inspection Guide* to determine when the safe posting load should be reduced based on the level of deterioration found during the inspection. Corrugated metal pipe culverts are typically posted for 3 or 15 tons. The policy can be found in the BEIM Appendix G.

Other factors such as the type of traffic, the likelihood of overweight vehicles, and posting enforcement levels may lead to safe posting loads that are lower than those determined above. The safe posting load is recommended by the BME and approved by the Chief Engineer.

2.4.2 Load Posting Timeline

In general, DelDOT requires the signed Load Posting Resolution to be distributed within 17 days of the load rating being finalized. The posting signs are required to be placed within 30 days of the Load Posting Resolution being distributed. Refer to the BIM *Inspection Activity Related Timeline* section for additional guidance on the typical DelDOT bridge inspection timeline, including reporting, load rating, and load posting activities.

2.5 Load Posting Guidance

DelDOT load rating policy supplements the guidance set forth in the various references discussed in this section.

2.5.1 NBIS

Refer to NBIS Sections 650.313 (c) and 650.315 (d). Section 650.313 (c) states bridges must be load rated in accordance with the AASHTO Manual. Bridge postings or restrictions should be in accordance with the AASHTO Manual and/or State law. Section 650.315 (d) sets forth the timing requirements for entering SI&A data into the State or Federal agency inventory. For changes in load restriction or closure status for State or Federal agency bridges, the SI&A data must be entered within 90 days of the change in status. For all other agency bridges, the SI&A data must be entered within 180 days of the change in status.

2.5.2 AASHTO MBE

Safe posting load serves as a guideline for establishing a posting weight limit for a structure. The safe posting load will typically be less than the load determined in the legal load rating. The following formula from the MBE will be used to determine the safe posting load for each vehicle type:

$$Safe\ Posting\ Load = \frac{W}{0.7}[(RF) - 0.3]$$

Where:

RF = Legal load rating factor (As determined in accordance with Section 1 of this Manual)

W = Weight of rating vehicle (kips)

Applicable values for RF are between 0.3 and 1.0. If a rating factor for any vehicle type falls below 0.3, then that vehicle type should *not* be allowed on the span. A bridge that has been assessed as being incapable of carrying a minimum gross live load of 3 tons shall be closed to traffic.

2.5.3 DE MUTCD

Posting signage shall conform to guidelines provided by the *Weight Limit Signs* section of the Delaware MUTCD. Multi-vehicle posting requires the posting signage to have a silhouette of each type of truck being posted and the safe posting load in tons for each truck type. The GVW posting will indicate a single weight limit in tons, which applies to all truck types. Example multi-vehicle posting and GVW posting signage is shown below.

Figure 2-1 GVW Posting Sign

Figure 2-2 Multi-Vehicle Posting Sign

2.5.4 FHWA FAST Act

When a load rating results in a rating factor less than 1.0 for the EV2 or EV3 emergency vehicles, the bridge must be load posted. Refer to the FHWA FAST Act for additional information. DelDOT uses the 2 and/or 3 axle single unit vehicle silhouette accordingly on posting signage for bridges that require posting for the EV2 or EV3.

If a bridge requires posting for the S335 Delaware Legal Load and the EV3 vehicles, then the most restrictive posting tonnage shall be used for the Load Restriction Resolution and on the posting signage. Typically, the posting tonnage for the S335 would be more restrictive. The same concept applies for the S220 Delaware Legal Load and the EV2 vehicles. When this occurs, the BME is to make note of this on the Load Rating Summary Form.

2.6 Load Posting Process

This section provides guidance on the Load Posting Process, including the steps to be followed and documentation requirements.

1. The BME implements a new load restriction, modification to an existing load restriction, or removal of an existing load restriction by preparing the Load Restriction Resolution. The Load Restriction Resolution is combined with the other items listed in 2.6.1 to create the Load Posting Document, which is sent to the Chief Engineer for signature. Section 2.6.1 identifies additional DelDOT staff that are to be copied when

sending the resolution to the Chief Engineer. The Chief Engineer will return the signed copy of the Load Restriction Resolution to the BME.

2. Upon receipt, the BME distributes the signed Load Posting Document to DelDOT's Chief Traffic Engineer and copies the proper authorities as indicated in Section 2.6.2.

3. Upon distribution of the Load Posting Document, DelDOT Signs and Markings will install, remove, or replace the regulatory signage as per the posting resolution in accordance with the DE MUTCD.

4. BMS will confirm that the proper signs have been installed within 30 days of distributing the signed Load Restriction Resolution or upon notification from Traffic that posting signage has been placed or removed. Any necessary correction to the signage will be directly communicated to DelDOT Signs and Markings by the BME for addressing. Refer to the BIM for the complete timeline for inspection related activities. Refer to Section 2.7 of this Manual for additional information about DelDOT procedures for load posting signage confirmation.

2.6.1 Load Posting Document

The following items are created and compiled by the BME and then emailed to the Chief Engineer for signature:

- Load Restriction Resolution
- Load Posting Truck Form
- Bridge Location Map

The email should include a brief description as to the reason for the posting resolution, the compiled load posting document, and a copy of the original posting resolution, if the resolution is for modification or removal of a posting. When sending the email to the Chief Engineer, the following individuals shall be included as well:

- Chief of Bridges & Structures
- Bridge Design Engineer
- Administrative Assistant to the Chief Engineer
- Director of Maintenance & Operations (M&O)
- Administrative Assistant to the Director of M&O

2.6.1.1 Load Restriction Resolution

The Load Restriction Resolution is the legal document that authorizes DelDOT to implement a load restriction in accordance with the Delaware Code. An example Load Restriction Resolution is included in Appendix 2-1.

2.6.1.2 Load Posting Truck Form

Template pdf forms have been created to identify the posting tonnages for all legal load vehicles. One form addresses new or posting modifications for existing bridges and a second form addresses posting removal resolutions. If the posting resolution is for a new or modified resolution, then any truck that does *not* require posting shall have the tonnage field left blank. If the posting is a single gross tonnage, then all truck tonnage fields shall be left blank and only the gross weight field. Sample documents are included in Appendix 2-2.

2.6.1.3 Bridge Location Map

The last item of the Load Posting Document includes a map depicting the location of the bridge and surrounding area. The map is created by taking a snippet from DelDOT's Bridge Atlas and saving it into a Word template document. The link to the DelDOT Bridge Atlas is as follows:

https://deldot.gov/Publications/manuals/bridge_atlas/index.shtml

Refer to Appendix 2-3 for an example.

2.6.2 Bridge Posting Distribution Letter

The next step in the posting resolution process is the distribution of the signed load posting document to various DelDOT Sections and outside agencies. The BME creates the draft letter for the Bridge Section Administrative Assistant to put on official letterhead, have the Chief of Bridges & Structures sign, and then generate the distribution email to all required recipients.

The posting distribution letter shall be sent along with the signed load posting document to the following DelDOT and outside agency personnel:

- DelDOT Traffic Section
- Delaware State Police
- School Superintendent and Transportation Supervisors
- DelDOT Public Relations
- DelDOT Maintenance
- DelDOT Transportation Management Center
- County Fireboard or Emergency Services Director
- Delaware Motor Transport Association
- Various DelDOT Signs and Markings Section personnel – this will trigger placement or removal of the load-posting signs

A sample Load Posting Distribution Letter is included in Appendix 2-4. BME maintains a contact list of individuals that are to be included on the distribution email. The contact list is saved on the network.

2.7 Load Posting Signage Confirmation

The Traffic Section will e-mail the BME when signs are placed, replaced, or removed. This will initiate the BME to schedule a field visit to confirm the correct signs have been placed, replaced, or removed. As part of the Posting Signage Verification process, a Bridge Posting Sign Location document is required to be created upon installation and placement of the proper signage (as shown in Appendix 2-5). The documentation will include a map of the bridge and surrounding area with the specific sign locations identified on the map. In addition, photos of each posting sign will be taken and assembled with the map into a document which will be stored within the bridge inspection file. Completion of the posting sign documentation will be noted in the internal tracking spreadsheet to close out the posting process for a bridge.

DelDOT utilizes the Bridge Posting Sign Location document to maintain NBIS compliance for bridge load posting activities and requirements as outlined in the BIM. Additionally, this document provides verification to the FHWA that the bridge was load posted and load posting signs properly installed as per the signed Load Restriction Resolution. In addition, the Bridge Posting Sign Location document may assist the BMS and Traffic Section with replacing signage in the future in cases when posting signs get mistakenly removed, vandalized, or damaged. This document shall be created, saved, and stored in the bridge inspection file by the BME.

If NBI Item 41 (Structure Open, Posted or Closed to Traffic) is coded as "P" (Posted for Load), inspection teams are required to check that all posting signs are present, visible, and in good condition. Refer to the posting sign documentation within the bridge inspection file to confirm the specified posting sign placement. Verify that the restricted/posted vehicles and weights on the sign match the most recent posting resolution in the bridge inspection file. Signage will be verified during routine bridge inspections by referring to the Bridge Posting Sign Location document. Bridge inspectors shall confirm the correct signage exists. Within 3 days of the inspection date, the inspection team leader is required to notify the BME if incorrect signage, missing signage, signage is not visible due to obstructions, or signage requires repair/replacement. The BME will report any issues with signage to the Signs and Markings Section.

2.8 Load Posting Document Storage

The Load Posting Document shall be stored both on the network and paper copy in inspection file.

The BME will compile and save the following items to be stored in the bridge inspection file:

- Posting Sign Location Document
- Load Posting Distribution Letter E-mail
- Load Posting Distribution Letter
- Load Posting Document
- E-mail from Chief Engineer with the signed Load Posting Document

All bridge posting activities will be tracked by the BME in the Bridge Posting Signs Tracking Report excel spreadsheet. The following fields are included in the spreadsheet:

- Posting Issue (New Posting, Posting Modification, Posting Removal, Missing Signs, Incorrect Signs, Damaged Signs)
- Description of Posting Issue
- Date of Latest Posting Resolution
- Date of Distribution Letter
- Signs and Markings Notification Date
- Date of Sign Placement, Removal, or Replacement
- Date Sign Placement Verified & Documented
- Updated Actions / Comments

2.9 Updating Load Posting Data in Database

BME is responsible for updating the BrM database as part of the process of the load rating being finalized. For a GVW posting, all legal loads in the database will be updated with the GVW posting load.

The following NBI Fields must be updated on the BrM Inspection / Appraisal page:

- Item 41 – Structure Open, Posted, or Closed to Traffic
- Item 70 * – Bridge Posting
- Rating Date
- Initials (Load Rater)
- Rating Data Fields #63-66

* Use Legal Load with highest percentage reduction of legal load

The following DelDOT Agency Fields must be updated on the Inspection / DelDOT Load Ratings page in BrM:

- Reason for Posting
- Date of Resolution
- S220 Posting Load
- S335 Posting Load
- S437 Posting Load
- T330 Posting Load
- T435 Posting Load
- T540 Posting Load
- SU4 Posting Load
- SU5 Posting Load
- SU6 Posting Load
- SU7 Posting Load
- EV2 Posting Load
- EV3 Posting Load

2.10 References

The Delaware Code
Legislative Council, General Assembly, State of Delaware

DelDOT Policy for Inspection and Load Posting of Corrugated Metal Culverts
Delaware Department of Transportation
January 2008 Publication

Delaware Manual on Uniform Traffic Control Devices
Delaware Department of Transportation
May 2018 Publication

Manual for Bridge Evaluation, 3rd Edition
American Association of State Highway and Transportation Officials (AASHTO)
2018 Publication

Appendix 2-1 – Load Restriction Resolution

LOAD RESTRICTION RESOLUTION

WHEREAS, Chapter 5, Title 17 §510, Delaware Code, as amended, provides that the Department of Transportation may determine the maximum weight of vehicles which can be safely driven across bridges in the control of the Department and may post such bridges for the maximum weight of vehicles that may operate over same, and

WHEREAS, an engineering investigation on Bridge No. 219 on Road No. 080 in Sussex County, indicates that the load limit should be modified for the vehicles and corresponding weights as identified on the following form due to a recent structural analysis of the bridge.

NOW, THEREFORE, BE IT RESOLVED that the Department, in accordance with the authority vested does hereby declare that the load limit on the above mentioned bridge at the location shown must be as per attachment and the restriction to become effective with the posting of the proper signs.

BE IT FURTHER RESOLVED that copies of this resolution be forwarded to the proper officials of the Department of Transportation and to the Superintendent of the Delaware State Police.

APPROVED ON 3-31-2020

CHIEF ENGINEER/DIRECTOR

Appendix 2-2 – Load Posting Truck Form

INFORMATION FOR BRIDGE POSTING MODIFICATION

COUNTY: Sussex

ROAD NO.: 080

BRIDGE NO.: 219

FEATURE INTERSECTED: Butler Mill Branch

REASON FOR MODIFICATION: A recent structural analysis was completed and the results show that the current posting restriction requires modifications as noted below.

POSTING:

Maximum Vehicle Gross Weight __ **Tons**

Delaware Legal Loads

S220: 2 Axle Single Unit  __ **Tons**

S335: 3 Axle Single Unit  33 **Tons**

S437: 4 Axle Single Unit  35 **Tons**

T330: 3 Axle Semi  __ **Tons**

T435: 4 Axle Semi  __ **Tons**

T540: 5 Axle Semi  __ **Tons**

AASHTO Legal Single-Unit, Specialized Hauling Vehicles (SHV's)

SU5: 5 Axle Single Unit  __ **Tons**

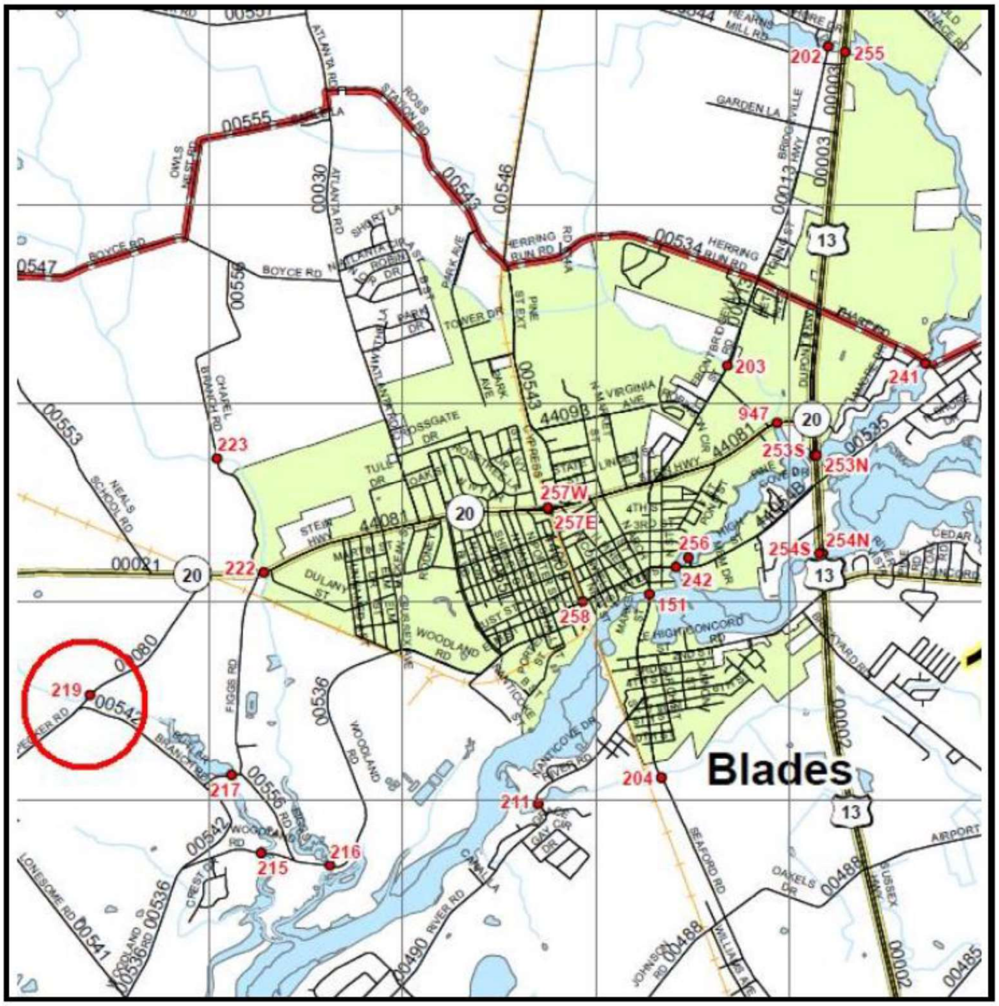
SU6: 6 Axle Single Unit  __ **Tons**

SU7: 7 Axle Single Unit  __ **Tons**

NOTE: **If the posting for a particular vehicle is blank, then legal load applies.**

LOCATION MAP ATTACHED

Appendix 2-3 – Location Map



Bridge 3-219-080
Location Map

Appendix 2-4 – Load Posting Distribution Letter

STATE OF DELAWARE
DEPARTMENT OF TRANSPORTATION
800 BAY ROAD
P.O. BOX 778
DOVER, DELAWARE 19903

JENNIFER COHAN
SECRETARY

April 1, 2020

Mr. Peter Haag
Chief of Traffic Engineering
Delaware Department of Transportation
169 Brick Store Landing Road
Smyrna, DE 19977

Dear Mr. Haag:

We are forwarding the approved resolution modification of bridge posting signs for Bridge No. 3-219-080, Woodpecker Road over Butler Mill Branch, West of Seaford, Sussex County, with a location map.

This resolution replaces the current load limits with the limits indicated on the attached pages on Bridge No. 219 on Road 080, Woodpecker Road in Sussex County. It is important to note, that fire/emergency service vehicles and buses are not restricted from use of the bridge. This is for your files.

Sincerely,

Jason N. Hastings, P.E.
Chief of Bridges & Structures

TEG/jh
Enclosure
cc: Lt. Robert Jones, Asst. Director, Traffic Operations Section, Delaware State Police
Joseph Thomas, Director, Sussex County Emergency Operations
Charles Dean, Education Associate, School Transportation, Dept. of Education
David P. Perrington, Superintendent, Seaford School District
Natosha Rivera, Transportation Specialist, Seaford School District
C.R. McLeod, Director of Public Relations, DelDOT
Louise Holt, Public Relations, DelDOT
Alastair Probert, South District Engineer, DelDOT
Jason Arndt, Bridge Management Engineer, DelDOT
Mark Harbeson, Traffic Field Operations Engineer, DelDOT
Gene Donaldson, Transportation Management Center, DelDOT
Ping Jiang, Load Rating Engineer, DelDOT
Nicholas Mogle, Signs and Markings, DelDOT (replace signs)
Erik Ball, Traffic Operations Manager, DelDOT
Kalli Riley, Sign Fabrication, DelDOT (Fabricate new signs)
Delaware Motor Transport Assoc.

DelDOT

Appendix 2-5 – Bridge Posting Sign Location Document

Bridge 3-219 Posting Sign Location Document

Index

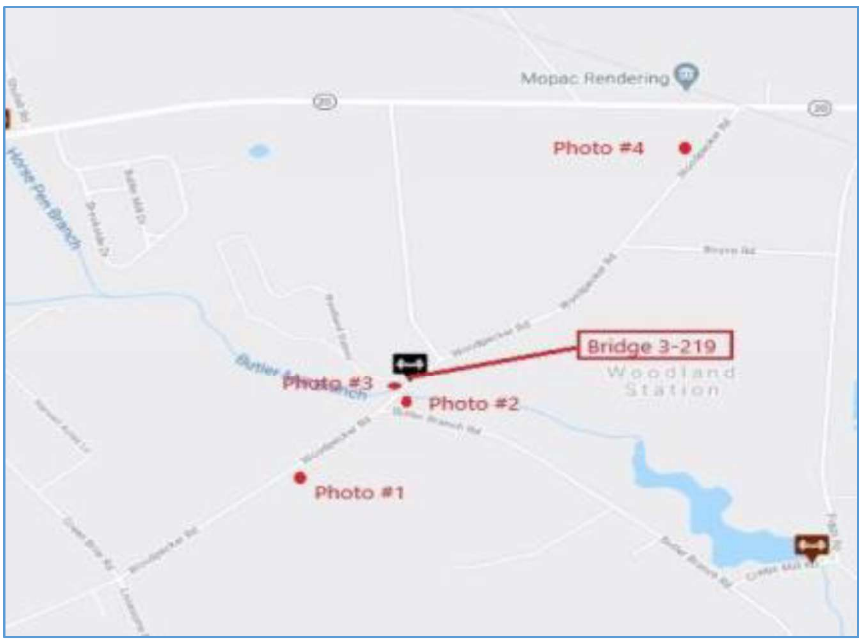


Photo 1 POSTING SIGN ALONG WOODPECKER RD WEST OF BUTLER MILL ROAD

Photo 2 SOUTH BRIDGE APPROACH POSTING SIGN

Photo 3 NORTH BRIDGE APPROACH POSTING SIGN

PHOTO 4 POSTING SIGN NEAR INTERSECTION OF SR20

Section 3 – Hauling Permit Reviews

3.1 Introduction

This section provides general guidance and DelDOT specific guidance for hauling permits.

3.2 Permit Program Objectives

The intent of the Oversize/Overweight Hauling Permit Program is to promote public safety, minimize impacts to the traveling public, minimize impacts/damage to public facilities, and to assign equitable fees to the movement of oversize/overweight goods throughout the State of Delaware. This program is managed by DelDOT's Traffic Safety Section. BMS participates in the review and approval of a portion of the overall permit applications, as described in subsequent sections.

Oversize / Overweight (OSOW) hauling permit applications are completed and submitted by the hauler directly through the DelDOT OSOW Permit System at: https://www.deldot.gov/osow/application/login

A sample permit data entry screen view can be found in Appendix 3-1.

Additional information regarding the online system can be found in the *State of Delaware Oversize/Overweight Permit System User's Guide for the On-Line Customer* on the OSOW webpage.

3.3 Permit Review Responsibility

Permits are reviewed and approved by several groups within DelDOT as listed below:

- Traffic Section
- Signal Maintenance Section
- Safety Section
- Materials Research Section
- Bridge Section

The areas of responsibility of each group are indicated in Figure 3-1 below.

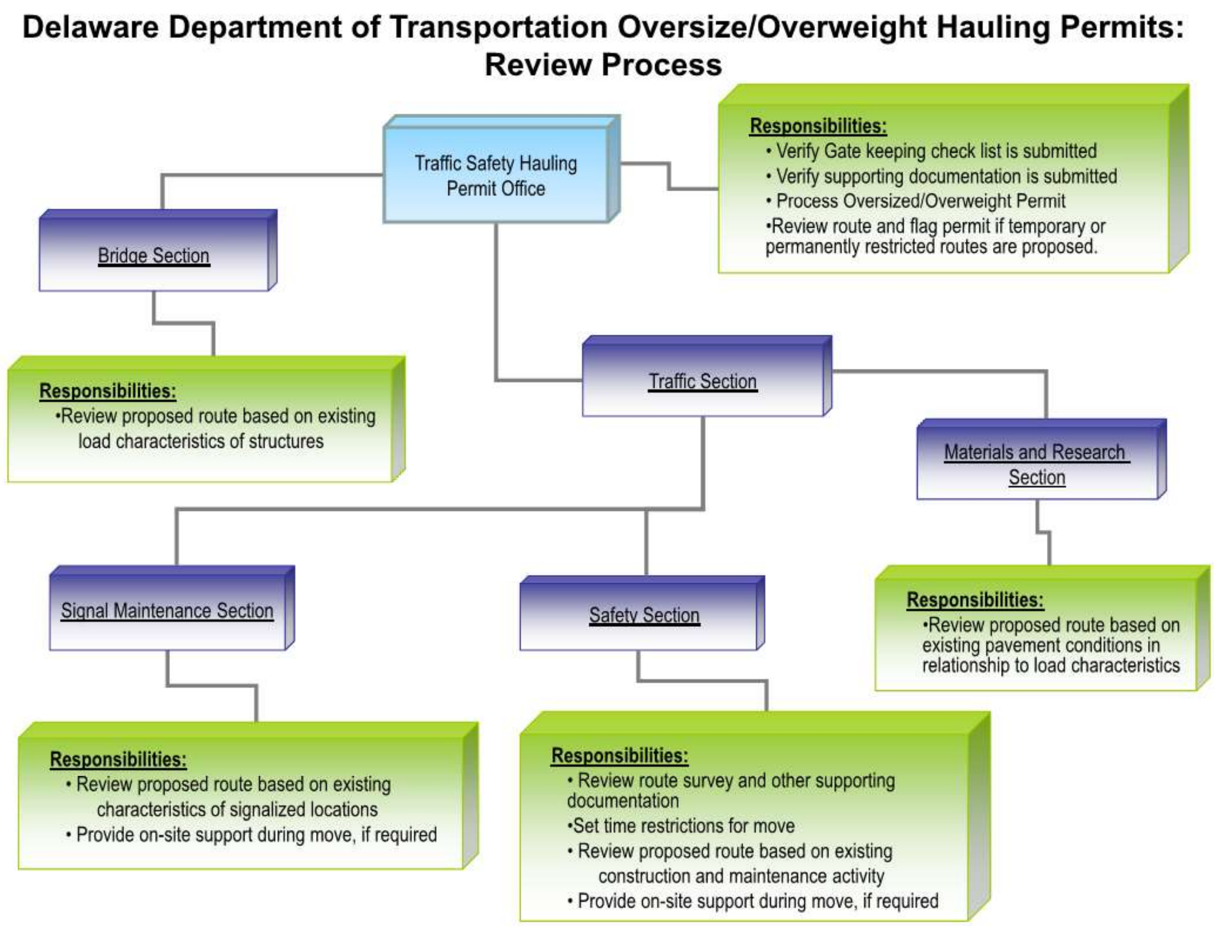


Figure 3-1 DelDOT OSOW Hauling Permits Review Process

DelDOT is responsible for issuing permits for all structures in the state of Delaware; however, DelDOT is *not* responsible for reviewing permits for structures owned by other stakeholders. Other owners are required to review the OSOW Hauling Permit, and then DelDOT will issue the permit based upon the other owner's approval.

3.3.1 Permit Review Process

This section summarizes the role and responsibilities of each department within the permit review process.

3.3.1.1 Traffic Section

The Traffic Section review involves the Signal Maintenance Section, Safety Section, and Materials Research Section. The Materials Research Section reviews permits involving axle weights greater than 25,000 pounds. Traffic Section coordinates with BMS for unusual circumstances, such as excessive vehicle height, width, or weight.

3.3.1.2 Bridge Section

The OSOW Manual defines Superloads as vehicles that meet *any* one of the following conditions:

- 15' or more in width,
- 15' or more in height, 120' or more in length,
- Gross Vehicle Weight (GVW) more than 120,000 pounds

The BMS only reviews permit applications for vehicles that have a GVW more than 120,000 pounds *or* any individual axle(s) exceeding 25,000 pounds, regardless of the GVW.

The LRE oversees the permit review process and assigns reviews to available project engineers. The reviewer logs into the Oversize / Overweight Permit System and checks for new permit applications (the system does not provide automatic notification).

The BMS also reviews Annual Permit Vehicle applications and provides comments to the DelDOT Traffic Safety Office concerning the vehicle or bridge restrictions.

3.3.1.3 United States Army Corps of Engineers

The United States Army Corps of Engineers (USACOE) owns and maintains four bridges over the Chesapeake & Delaware (C&D) Canal in Delaware. The bridges are as follows:

Owner	Bridge Number	Facility Carried	Feature Intersected	Location of Bridge
USACOE	1495 034	US ROUTE 13	C & D CANAL	4.5 MI. W. OF REEDY POINT
USACOE	1494 016	DEL 896	C&D CANAL	9 MI. W. OF REEDY POINT
USACOE	1496 002	DELAWARE RT. 9	C&D CANAL	0.5 MI. S. OF DEL. CITY
USACOE	1902 082	KOREAN WAR VET MEM/SR1	C&D CANAL, RD 412	C&D CANAL

Permit Vehicles crossing bridges owned by USACOE with GVW greater than or equal to 150,000 pounds must be sent to USACOE for review. The BMS permit reviewer sends an e-mail with the permit details to the USACOE. The USACOE will send an approval, approval with restrictions, or rejection e-mail back to the BMS, who will then approve or reject the permit accordingly through the OSOW website.

3.3.1.4 Delaware River and Bay Authority

The Delaware River and Bay Authority (DRBA) owns and maintains twelve bridges on I-295 in New Castle and US-9 in Lewes. Permits for ten of these bridges are processed directly by the BMS using the procedures outlined in Section 3.6 of this Manual. DRBA reviews permits for the Delaware Memorial Bridges, which are as follows:

Owner	Bridge Number	Facility Carried	Feature Intersected	Location of Bridge
DRBA	1737A056	I 295 N & US 40 E	DELAWARE RIVER	NEW CASTLE
DRBA	1737B056	I 295 S & US 40 W	DELAWARE RIVER	NEW CASTLE

Permit vehicles shown in the table above with GVW greater than 120,000 pounds or vehicles containing any individual axle(s) exceeding 25,000 pounds must be sent to DRBA for review. The BMS permit reviewer sends an e-mail with the permit details to DRBA. DRBA will send an approval, approval with restrictions, or rejection e-mail back to the BMS, who will then approve or reject the permit accordingly through the OSOW website.

3.3.2 Bridge Loading

DelDOT BMS uses the QPermit program to assess the structural adequacy of all bridges along a permit route for a given Superload permit vehicle. Details on the use of the QPermit program are provided in subsequent sections.

3.3.3 Bridge Clearances

DelDOT BMS uses the QPermit program to assess the bridge underclearance of all bridges spanning over a permit route for a given Superload permit vehicle. Details on the use of the QPermit program are provided in subsequent sections. The DelDOT Bridge Clearances data is stored in the DelDOT Clearances page of the Inspection module of the BrM database. If a more detailed evaluation of the vertical under or over clearance for a bridge is needed, the Underclearance Sketch sheet(s) from the most recent inspection can be accessed via the inspection files.

3.3.4 Sign Structure Clearances

DelDOT BMS maintains a sign structure database which contains the underclearance of all DelDOT sign structures. This database is used by the Traffic Section to evaluate if sign structure underclearances of all structures spanning over a permit route are adequate for a given permit vehicle.

3.4 Hauling Permit Legislation & Codes

The authority of the Department of Transportation to issue OSOW permits is dictated by the Delaware Code. Procedures for analyzing permit loads on bridges are governed by the NBIS and MBE requirements.

3.4.1 Delaware Code

Chapter 45, Section 4504 of Title 21 of the Delaware Code delegates authority to DelDOT to establish rules and regulations including setting fees as required to comply with the laws of the State of Delaware and the laws of the Federal Government. A permit shall be required for movement on highways in the State of Delaware when any vehicle, vehicle combination, vehicle, and load combination, and/or equipment or machinery being moved under its own power exceeds the dimensional and/or weight limits set forth in Chapter 45, Title 21 of the Delaware Code.

3.4.2 NBIS

Bridge files shall be prepared as described in the AASHTO Manual (MBE). The following items shall be maintained such that the condition of all bridges may be assessed.

- Bridge Inspection Reports
- Under/Overclearance Data
- Plans
- Load Ratings
- Records of repairs made to address Bridge Inspection findings
- Maintenance records
- Bridge Load Posting Resolution documents

The BMS is responsible for updating the abovementioned information in the Bridge Database. This information is required and accessed by the QPermit program for permit analysis.

3.4.3 MBE Requirements

Typically, the permits issued are Routine (Annual) Permits and Special (Limited Crossing) Permits. Annual permits are issued for unlimited travel for a vehicle of specified configuration, axle weights, and gross weight. Vehicles with very heavy loads are more likely to require a special permit. Special permits are typically issued for a single trip only for a vehicle of specified configuration, axle weights, and gross weight. These permits may have more stringent criteria, such as the vehicle requiring escort to control speed, lane position, presence of other vehicles on the bridge, etc.

When evaluating a vehicle for issuance of a permit, the live load considered should accurately reflect the truck’s weight, axle configuration, designated lane position, and any speed restrictions.

For further guidance related to permit load analysis and permit load factors, refer to the Section 1 of this Manual.

3.5 Hauling Permit Requirements

Hauling permit requirements are provided in the OSOW Manual.

3.5.1 Bridge Section Review Thresholds

The BMS is responsible for reviewing permits for the vehicles that meet the Superload criteria as defined in Section 3.3.1.2 of this Manual. The BMS also reviews Annual Crane permit applications for vehicles submitted as Load Code 11 as defined in the OSOW Manual. Annual Crane permits do not have a specified route; therefore, the crane has the possibility to cross any bridge within the state, unless specifically restricted by BMS upon review and evaluation of the permit request. In addition, Annual Cranes cannot cross load posted bridges.

3.5.2 Permit Review Timeline

Permits will be reviewed by the Department within ten business days of submission in accordance with the DelDOT OSOW Manual. It is the goal of BMS to review permits within three business days.

3.6 Hauling Permit Review Process

BMS is responsible for reviewing and processing Superload permit applications during each business day except for State & Federal Holidays. Occasionally, BMS is called to review an emergency permit application outside of normal working hours. In each of these permit applications, the hauler is requesting to cross specific bridges based on the selected permit route. BMS also reviews Annual Crane permits, which may cross any bridge in the state, unless restrictions are imposed during the approval of the permit. It isn't feasible to analyze each bridge for each permit vehicle and process the permit applications within the time constraints of the OSOW program. Therefore, DelDOT has developed a permit screening process to streamline the review of permit applications and meet the required timelines. This screening process utilizes the Federal Bridge Formula and the HS20-44 design vehicle to estimate each bridge's capacity to support a given permit vehicle. Since an individual set of bridge design computations cannot be done for every type of truck that may use a particular highway, bridge designers have historically used a standard vehicle, the HS20-44, for estimating critical stresses, strains, or deflections in a bridge structure. The Federal Bridge Formula calculates the maximum allowable load (the total gross weight in pounds) that can legally be imposed on the bridge by any group of two or more consecutive axles on a vehicle or combination of vehicles. If a vehicle conforms to the bridge formula, then it will not cause bridge structure stresses, strains or deflections that exceed those critical values calculated using the standard HS20-44 design vehicle. In effect, it helps to ensure bridges are not "overstressed" due to the almost infinite number of truck-axle configurations and weights. The bridge formula reflects the fact that loads concentrated over a short distance are generally more damaging to bridges than loads spread over a longer distance. It provides for additional gross weight as the wheelbase lengthens and the number of axles increases. The Federal Bridge Formula was implemented by Congress to determine the maximum allowable GVW of a vehicle travelling on the Interstate highway system. Title 21, Chapter 45 of the Delaware Code also limits GVW on the Interstate highway system to the Federal Bridge Formula. In the screening process, an Equivalency Factor is calculated that represents the relative load effect of the permit vehicle as compared to the maximum GVW as determined by the Federal Bridge Formula. The detailed procedures that DelDOT uses to screen permit vehicles are described in subsequent sections of this Manual.

3.6.1 Federal Bridge Formula

As implemented by Congress and Chapter 45, Title 21 of the Delaware code, the maximum gross weight of any vehicle or group of two or more consecutive axles as allowed on the Interstate highway system is calculated by the Federal Bridge Formula as follows:

$$W = 500\,[\frac{L * N}{N - 1} + 12 * N + 36]$$

Where,

W = Overall Gross Weight of any group of two or more consecutive axles to the nearest 500 lb

L = Distance between the extreme of any group of two or more consecutive axles (ft)

N = Number of axles in the group under consideration

In addition to Federal Bridge Formula weight limits, Federal law states that single axles are limited to 20,000 pounds, and axles spaced more than 40 inches, and not more than 96 inches apart (tandem axles) are limited to 34,000 pounds. GVW is limited to 80,000 pounds.

The latest details of the Federal Bridge Formula can be found in *Bridge Formula Weights* published by FHWA in August 2019.

This equation requires numerous calculations depending upon the configuration of the vehicle. The allowable weight must be calculated for each axle group. The allowable weight for the vehicle is the sum of the allowable weights for each axle group. The gross weight obtained from this equation will be used to calculate the Equivalency Factor.

3.6.2 Equivalency Factor

The GVW of Superloads and Annual Permit Vehicles normally exceed the maximum gross weight calculated by the Federal Bridge Formula for the axle configuration of the respective permit vehicle. DelDOT calculates an Equivalency Factor to determine relative load effect of the permit vehicle compared to the Federal Bridge Formula maximum weight which correlates to the HS20-44 design load. The Equivalency Factor is computed as follows:

EF = PW / W

Where,

EF = Equivalency Factor

PW = Actual Weight of the axle or group of axles of the Permit Vehicle

W = Max Allowable Weight as determined by the Federal Bridge Formula or federal law for the axle or group of axles. Refer to Section 3.6.1.

The maximum Equivalency Factor is the highest calculated value for any axle or group of axles on the permit vehicle. Refer to Appendix 3-3 for an example of the Equivalency Factor calculation procedure.

3.6.3 Bridge Load Ratings

The Permit Screening process compares the applied load effect from each permit vehicle, as estimated using the Equivalency Factor determined in section 3.6.2, with each bridge's Live Load Effect capacity, as determined by the bridge load rating. Because the applied live load of the permit vehicle has been normalized to the Maximum Allowable Weight in Section 3.6.2, it can be compared to the HS20-44 Load Rating Factor. However, before the Equivalency Factor and the HS20-44 Load Rating Factor may be directly compared, the Design Operating Live Load Factor used to determine the HS20-44 Load Rating Factor must be multiplied out and the Permit Live Load Factor must be divided in. For each unlimited/single-trip restriction case a different Permit Live Load Factor must be divided in, and different combinations of multiple presence and impact factors may also have to be multiplied out, as described in Section 3.6.3.2. The HS20-44 Operating Ratings and the modified HS20-44 Permit Ratings are stored for each bridge in the permit analysis fields in the DelDOT Load Ratings page of the Inspection module in the BrM database. These fields are updated by the BME as the load rating is finalized.

3.6.3.1 HS20 Operating Rating

The HS20 Operating Rating Factor is calculated by performing a design rating for AASHTO HS20-44 live load with a Live Load factor of 1.35 as specified in Section 1. The rating factor is based on the critical case of one lane or multiple lanes loaded.

$RF_{HS20} = (\text{Capacity} - DL)/[LF_{design}(MP * LL_{HS20} + IM)]$

MP = Multiple Presence – Applied directly through the calculated distribution factors, if used

DelDOT modifies the HS20 Operating Rating to account for variations in Live Load Factor, Multiple Presence Factor, and Impact Factors associated with an unlimited/single trip crossing and various restrictions that may be applied to the permit vehicle. Possible restrictions that can be applied to a permit vehicle include *No Other Vehicles on Bridge* and *Reduced Speed*. The live load factors for permit loads are in accordance with the MBE.

3.6.3.2 Permit Vehicle Restrictions

A spreadsheet that calculates and stores the rating factor for the various configurations of restrictions imposed on the permit vehicle for each bridge is maintained by the BME and stored on the network. Input fields for the spreadsheet include:

- Dynamic Impact Factor Used in Rating
- HS20 Operating Rating (tons)

The rating factors associated with the following restrictions are calculated in the spreadsheet:

- Unlimited Crossings
- Single Trip / Mix with Traffic
- Single Trip / No Traffic
- Single Trip / Mix with Traffic / No Impact
- Single Trip / No Traffic / No Impact

3.6.4 QPermit

QPermit is a DelDOT in-house computer program that is used by BMS to screen the bridges along a route that have been identified in a Superload permit application. The permit vehicle axle weights and spacing, vehicle height, and the origin and destination of the permit route are obtained from the OSOW permit data by the QPermit program. The Reviewer will also define the bridges along the proposed route. QPermit computes the Equivalency Factor for the permit vehicle and compares the Equivalency Factor to each bridge's HS20-44 Permit Load Rating Factors for bridges carrying the proposed route. QPermit also checks the over and underclearance for bridges spanning over the permit route and compares them to the permit vehicle height. The Analysis Results from QPermit are used by the Reviewer to approve, apply restrictions to the permit vehicle, or to perform further analysis on one of more of the bridges on the route. An example QPermit Analysis Results Screen can be found in Appendix 3-2.

3.6.5 QPermit Screening Criteria

The Equivalency Factor is used to determine if the permit vehicle can proceed on the proposed bridge with or without any restrictions. The Equivalency Factor compared to the bridge load ratings as follows:

- For Max Span Length > 8'

  The maximum Equivalency Factor of the permit vehicle is compared to the appropriate load rating factor of the bridge.

- For Max Span Length < 8'

The Equivalency Factor associated with the Max Axle Weight of the permit vehicle (in Pounds) is compared to (32,000 * the appropriate load rating factor of the bridge).

3.6.6 QPermit Output

The QPermit program returns the following information in a report about the permit vehicle and the bridges on or over the selected route:

- Maximum Equivalency Factor
- Underclearance Check
- Permit Restrictions

This information is used by the reviewer to approve, reject, and apply restrictions to the permit application.

3.6.6.1 Maximum Equivalency Factor

The Maximum Equivalency Factor is calculated for every axle group on the permit vehicle as described in Section 3.6.2. QPermit lists the controlling Equivalency Factor and axle grouping associated with each axle. The greatest of these is used by QPermit in the analysis of each bridge entered based on the selected route.

3.6.6.2 Underclearance and Overclearance Check

If the "Check Vert. Clearance" box is checked on the QPermit analysis screen, the QPermit Report will include the results of the comparison of the Permit Vehicle height to the bridge underclearance and overclearance for each bridge entered for the selected route. Any bridge that does not meet the vertical clearance check will be manually reviewed by the Reviewer.

3.6.6.3 Permit Restrictions

Qpermit will compare the Maximum Equivalency Factor of the permit vehicle with the load rating associated with the HS-20 vehicle or any restrictions as described in Section 3.6.5.1. The QPermit Report will contain a result for each bridge on the selected route as shown in Table 3-1 below.

QPermit Output Restrictions					
Mix with Traffic	No Traffic	No Impact	Equivalency Factor < RF	Equivalency Factor > RF	QPermit Analysis Result
✓			✓		OK (No Restrictions)
	✓		✓		Permit vehicle can proceed without any other vehicles on bridge while crossing
✓		✓	✓		Permit vehicle can proceed with 10 mph speed on bridge while crossing bridge
	✓	✓	✓		Permit vehicle can proceed with 10 mph speed on bridge and no other vehicles while crossing bridge
				✓	BRASS Required (Analysis Required)

Table 3-1 QPermit Output Restrictions Table

3.6.7 Permit Review Process for Single Trip Superload Permits

The maximum Equivalency Factor for the permit vehicle is obtained by QPermit using the method described in the previous evaluation procedure. Then, QPermit will compare the maximum Equivalency Factor with the load ratings associated with the various restrictions as shown in Figure 3-2 above and following the logic outlined in the subsequent sections. For examples, refer to Appendix 3-4. For Single Trip Permit Vehicles, starting with the single trip / mixed with traffic load factor, QPermit will find a load factor which is greater than the maximum equivalency factor by following the chart left to right.

The following steps discuss the DelDOT process for reviewing Oversize / Overweight Hauling Permits for Superloads.

1. Review permit data from the OSOW Permit website. Data includes vehicle dimensions (height and width), axle spacing configuration and weight, and travel route.

2. Reviewer assembles the list of bridges along and spanning over the travel route.
3. Reviewer logs into QPermit and selects the permit for analysis. QPermit automatically populates the permit vehicle details and the travel route for the selected permit. QPermit does not update the list of active permits automatically. The user must restart the program to generate a current list.
4. Reviewer enters the bridge list from Step 2 into QPermit. The bridges are selected from a pre-populated bridge inventory data list in QPermit. If the permit route is a commonly used route, the BMS permit reviewer can copy the list from a spreadsheet. Otherwise, the BMS permit reviewer enters the bridges directly into QPermit.
5. Reviewer selects "Check Vert. Clearance." box in QPermit.
6. Reviewer runs QPermit to check load capacity and underclearance.
7. QPermit will return a list of Equivalency Factors and Underclearance Status for each bridge on the selected list.
8. Reviewer verifies the QPermit output. For each bridge in the QPermit output, one of the following analysis results is reported:
   - OK – The bridge has adequate structural capacity for the permit load.
   - Permit Vehicle Restriction – QPermit will return one of several restrictions based upon the capacity of a given bridge, such as restricting other vehicles on the bridge and/or reducing travel speed of permit vehicle.
   - BRASS Required – The reviewer will run a BRASS load rating file using the permit vehicle axle weight and spacing configuration. If the BRASS load rating returns a load rating greater than 1.0, no further action is required. If the BRASS load rating returns a load rating less than 1.0, the bridge does not have adequate capacity. In this case, the load rating is revised to apply restrictions, such as restricting other vehicles on the bridge and/or reducing travel speed of a permit vehicle to reduce the dynamic impact loading. If the revised BRASS load rating returns a load rating factor greater than 1.0 after applying these restrictions, the Reviewer will list any applicable restrictions for that specific bridge under the special provisions. Otherwise, a new route would be recommended by BMS. The BMS Permit Reviewer will enter the recommended route into the comment sections of the permit. The Traffic Section will evaluate the route and, if acceptable (or an alternate route is proposed), the permit will be returned to BMS for approval.
9. Reviewer logs into OSOW Permit website and enters all applicable restrictions into the special provision text field.
10. If any bridges along the route have insufficient capacity to support the permit load, the reviewer will enter an alternate route into the OSOW Permits website. Provided an alternate route can be found, the permit will be approved with special provisions. If no alternate route can be determined, the permit will be rejected.

3.6.8 Permit Review Process for Annual Crane Permits

For Annual Permit Vehicles, screening will be performed for all bridges in the inventory using the process described in Section 3.6.5. The screening process is performed via a spreadsheet program developed specifically for Annual Crane Permits instead of QPermit. However, QPermit is used to obtain the calculated Equivalency Factor for the Annual Crane vehicle. Any bridge that does not have an HS20 Operating or modified Rating Factor greater than the Equivalency Factor for the actual permit vehicle will be identified as "rejected." If the "rejected" bridge does not have Rating Factor data for the standard Annual Crane permit vehicles, then it will be identified as "restricted" in the permit special provisions. If the "rejected" bridge contains the standard Annual Crane permit rating factor data, then it will be re-screened comparing the Rating Factor for the corresponding standard Annual Crane permit vehicle with a prorated rating factor for the actual permit vehicle. The prorated rating factor for the Permit Vehicle is calculated by dividing the GVW of the corresponding standard Annual Crane permit vehicle by the GVW of the actual permit vehicle. This factor is then multiplied by the rating factor of the corresponding standard Annual Crane permit vehicle. If the prorated rating factor for the actual permit vehicle is less than 1.0, then the bridge will be identified as "restricted" in the permit special provisions.

3.6.9 BRASS Load Rating Analysis

If QPermit returns "BRASS required" in the Analysis Results, the Reviewer will retrieve the BRASS data file(s) associated with the controlling load rating for the bridge under review.

3.6.9.1 Special Truck Commands

The Permit Vehicle will be entered into the BRASS data file as a Special Vehicle in the Live Loads section of the BRASS data, using the axle weights and spacings obtained from the permit data. The Reviewer will perform a Permit Rating for the Special Vehicle using a Live Load Factor of 1.20, assuming the permit vehicle will mix with other vehicles on the bridge. If the BRASS rating is greater than 1.0, the Permit Vehicle can proceed on the bridge without any restrictions.

3.6.9.2 Special Vehicle Restrictions

If the initial BRASS rating is less than 1.0, the Reviewer will modify the Live Load Factor and Impact factor associated with Special Vehicle Restrictions to obtain a rating greater than 1.0, in the following order:

1. No Other Vehicles on the Bridge
2. Reduced Speed
3. No Other Vehicles on the Bridge and Reduced Speed

The first restriction that returns a BRASS rating greater than 1.0 will be entered as a special provision in the permit by the Reviewer. If all the BRASS rating runs result in ratings less than 1.0, then an alternate route must be investigated.

3.7 Permit Document Storage

The Original Permit, the Approved Permit with Special Provisions, QPermit output, and BRASS output (if applicable) shall be stored on the network by the BMS Permit reviewer.

3.8 References

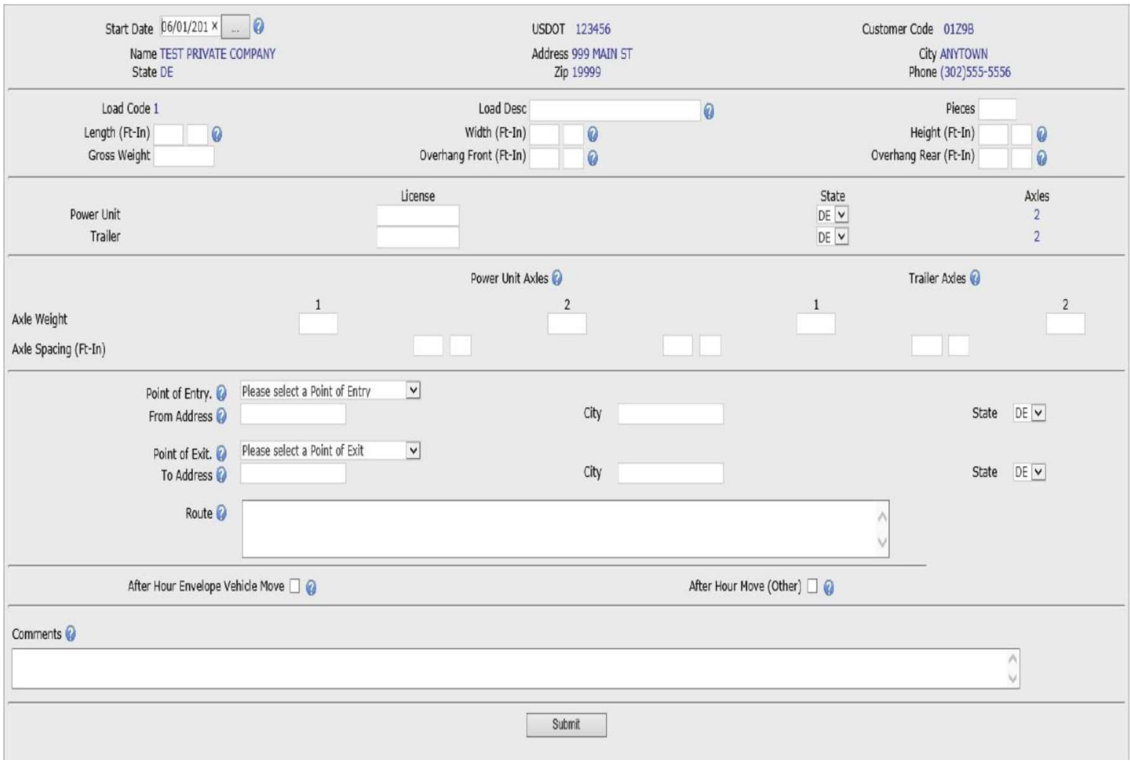
Oversize/Overweight Hauling Permit Policy and Procedures Manual
Delaware Department of Transportation
2018 Publication

The Delaware Code
Legislative Council, General Assembly, State of Delaware

Manual for Bridge Evaluation, 3rd Edition
American Association of State Highway and Transportation Officials (AASHTO)
2018 Publication

Bridge Formula Weights
FHWA
August 2019

Appendix 3-1 – Sample Permit



Start Date 06/01/201 ×
USDOT 123456
Customer Code 01Z98
Name TEST PRIVATE COMPANY
State DE
Address 999 MAIN ST
Zip 19999
City ANYTOWN
Phone (302)555-5556

Load Code 1
Load Desc
Pieces
Length (Ft-In)
Width (Ft-In)
Height (Ft-In)
Gross Weight
Overhang Front (Ft-In)
Overhang Rear (Ft-In)

	License	State	Axles
Power Unit		DE	2
Trailer		DE	2

Power Unit Axles 1 2
Trailer Axles 1 2
Axle Weight
Axle Spacing (Ft-In)

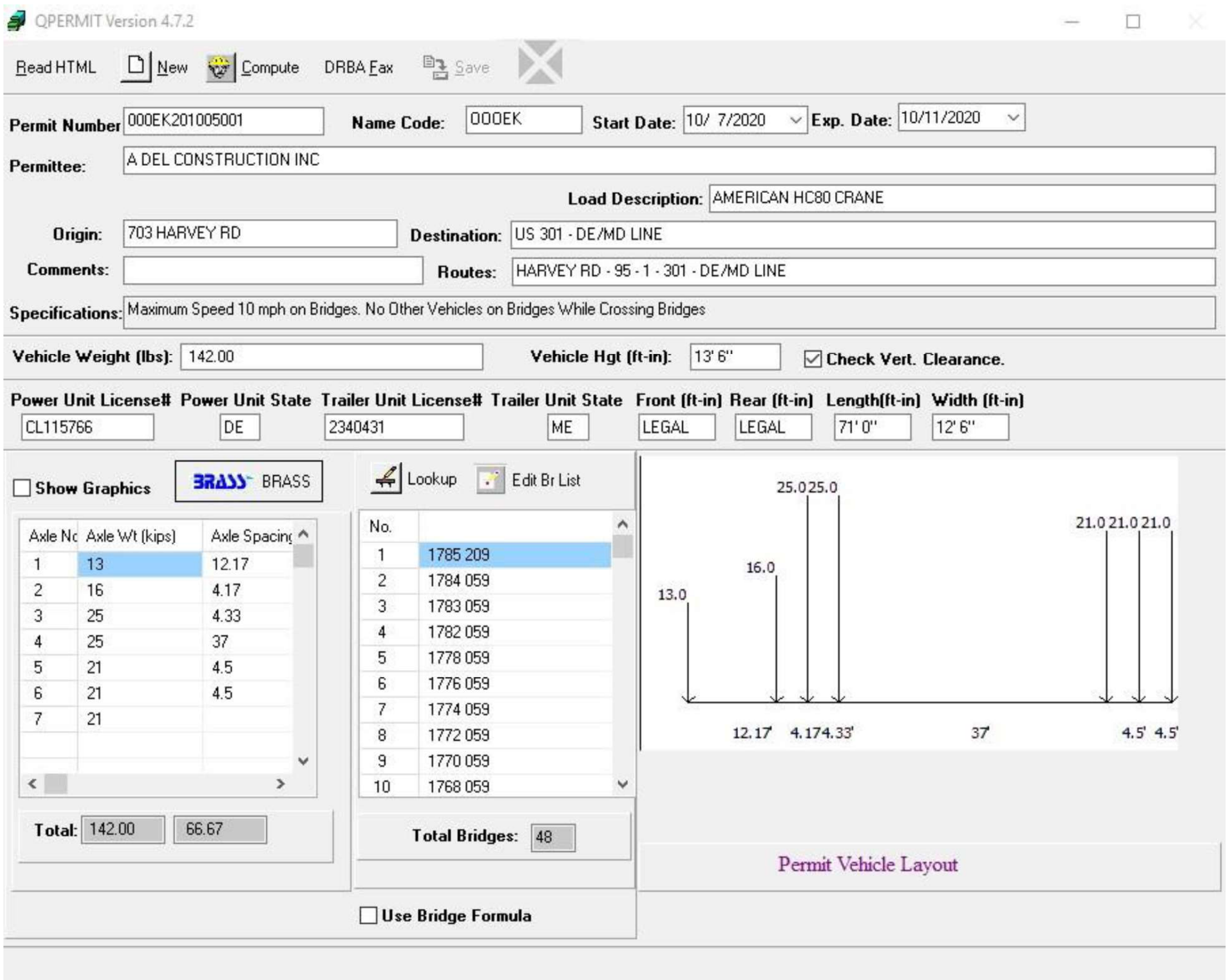
Point of Entry. Please select a Point of Entry
From Address
City
State DE
Point of Exit. Please select a Point of Exit
To Address
City
State DE
Route

After Hour Envelope Vehicle Move
After Hour Move (Other)

Comments

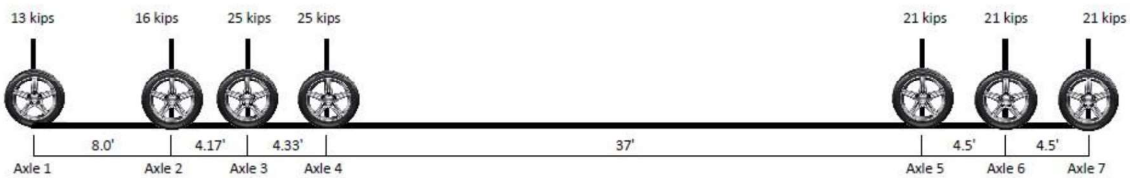
Submit

Appendix 3-2 – QPermit Analysis Screen



Appendix 3-3 – Equivalency Factor Example

The permit vehicle shown below will be used to show how the Equivalency Factor is calculated. The maximum weight W is calculated using the Federal Bridge Formula for each possible group of axles.



Equivalency Factor Calculations

Check for max single axle weight

Max Actual Axle Weight, ***W(actual)*** = 25,000 lbs.
Max Allowable Axle Weight, ***W(max)*** = 20,000 lbs.

Equiv. Factor = W(actual)/W(max) = 25,000/20,000 = 1.25

Checking for max tandem axle weight combination

Max Actual Axle Weight Combination, ***W(actual)*** = 42,000 lbs.
Max Allowable Axle Weight, ***W(max)*** = 34,000 lbs.

Equiv. Factor = W(actual)/W(max) = 42,000/34,000 = 1.24

<u>Checking for axles 1 & 2 using the above figure</u>

W (actual weight) =13,000 + 16,000 = 29,000 lbs.

N = 2 axles; L = 12.17 feet

$$= 500\left[\frac{L * N}{N - 1} + 12 * N + 36\right]$$

$$= 500\left[\frac{12.17 * 2}{2 - 1} + 12 * 2 + 36\right]$$

W (max weight) = 42,170 lbs.

Equiv. Factor = W(actual)/W(max) = 29,000/42,170 = 0.688

<u>Now check axles 2 & 3 using the above figure.</u>

W (actual weight) = 16,000 + 25,000 = 41,000 lbs.

N = 2 axles; L = 4.17 feet

$$= 500\left[\frac{L * N}{N - 1} + 12 * N + 36\right]$$

$$= 500\left[\frac{4.17 * 2}{2 - 1} + 12 * 2 + 36\right]$$

W (max weight) = 34,170 lbs.

Equiv. Factor = W(actual)/W(max) = 41,000/34,170 = 1.200

<u>Now check axles 1 through 3 using the above figure.</u>

W (actual weight) = 13,000 + 16,000 +25,000 = 54,000 lbs

N = 3 axles; L = 12.17 + 4.17 = 16.34 feet

$$= 500\left[\frac{L * N}{N - 1} + 12 * N + 36\right]$$

$$= 500\left[\frac{66.67 * 7}{7 - 1} + 12 * 7 + 36\right]$$

W (max weight) = 48,255 lbs.

Equiv. Factor = W(actual)/W(max) = 54,000/48,255 = 1.119

Now check axles 1 through 4 using the above figure.

W (actual weight) = 13,000 + 16,000 +25,000 +25,000 = 79,000 lbs.

N = 4 axles; L = 12.17 + 4.17 + 4.33 = 20.67 feet

$$= 500\left[\frac{L*N}{N-1} + 12*N + 36\right]$$

$$= 500\left[\frac{20.67*4}{4-1} + 12*4 + 36\right]$$

W maximum = 55,780 lbs.

Equiv. Factor = W(actual)/W(max) = 79,000/55,780 = 1.42

Now check axles 2-4 using the above figure.

W (actual weight) = 16,000 + 25,000 + 25,000 = 66,000 lbs

N = 3 axles; L = 4.33 + 4.17 = 8.5 feet

$$= 500\left[\frac{L*N}{N-1} + 12*N + 36\right]$$

$$= 500\left[\frac{8.5*3}{3-1} + 12*3 + 36\right]$$

W maximum = 42,375 lbs.

Equiv. Factor = W(actual)/W(max) = 66,000/42,375 = 1.558

Now check axles 2 through 5 using the above figure.

W (actual weight) = 16,000 + 25,000 +25,000 + 21,000 = 87,000 lbs.

N = 4 axles; L = 37 + 4.33 + 4.17 = 45.5 feet

$$= 500\left[\frac{L*N}{N-1} + 12*N + 36\right]$$

$$= 500\left[\frac{45.5*4}{4-1} + 12*4 + 36\right]$$

W (max weight) = 72,333.33 lbs.

Equiv. Factor = W(actual)/W(max) = 87,000/72,333.33 = 1.203

<u>Now check axles 3 through 5 using the above figure.</u>

W (actual weight) = 25,000 +25,000 + 21,000 = 71,000 lbs.

N = 3 axles; L = 37 + 4.33 = 41.33 feet

$$= 500\left[\frac{L*N}{N-1} + 12*N + 36\right]$$

$$= 500\left[\frac{41.33*3}{3-1} + 12*3 + 36\right]$$

W (max weight) = 66,997.5 lbs.

Equiv. Factor = W(actual)/W(max) = 71,000/66,997.5 = 1.060

<u>Now check axles 3 through 6 using the above figure.</u>

W (actual weight) = 25,000 +25,000 + 21,000 + 21,000 = 92,000 lbs.

N = 4 axles; L = 4.5 + 37 + 4.33 = 45.83 feet

$$= 500\left[\frac{L*N}{N-1} + 12*N + 36\right]$$

$$= 500\left[\frac{45.83*4}{4-1} + 12*4 + 36\right]$$

W (max weight) = 72,553.33 lbs.

Equiv. Factor = W(actual)/W(max) = 92,000/72,553.33 = 1.268

<u>Now check axles 2 through 6 using the above figure.</u>

W (actual weight) = 16,000 + 25,000 +25,000 + 21,000 + 21,000 = 108,000 lbs.

N = 5 axles; L = 4.5 + 37 + 4.33 + 4.17 = 50.00 feet

$$= 500\left[\frac{L*N}{N-1} + 12*N + 36\right]$$

$$= 500\left[\frac{50.00*5}{5-1} + 12*5 + 36\right]$$

W (max weight) = 79,250 lbs.

Equiv. Factor = W(actual)/W(max) = 108,000/79,250 = 1.363

Now check axles 2 through 7 using the above figure.

W (actual weight) = 16,000 + 25,000 +25,000 + 21,000 + 21,000 + 21,000 = 129,000 lbs.

N = 6 axles; L = 4.5 + 4.5 + 37 + 4.33 + 4.17 = 54.50 feet

$$= 500\left[\frac{L * N}{N - 1} + 12 * N + 36\right]$$

$$= 500\left[\frac{54.5 * 6}{6 - 1} + 12 * 6 + 36\right]$$

W (max weight) = 86,700 lbs.

Equiv. Factor = W(actual)/W(max) = 129,000/86,700 = 1.488

Now check axles 3 through 7 using the above figure.

W (actual weight) = 25,000 +25,000 + 21,000 + 21,000 + 21,000 = 113,000 lbs.

N = 5 axles; L = 4.5 + 4.5 + 37 + 4.33 = 50.33 feet

$$= 500\left[\frac{L * N}{N - 1} + 12 * N + 36\right]$$

$$= 500\left[\frac{50.33 * 5}{5 - 1} + 12 * 5 + 36\right]$$

W (max weight) = 79,456.25 lbs.

Equiv. Factor = W(actual)/W(max) = 113,000/79,456.25 = 1.422

Now check axles 1 through 7 using the above figure.

W (actual weight) = 13,00 + 16,000 + 25,000 +25,000 + 21,000 + 21,000 + 21,000 = 142,000 lbs.

N = 7 axles; L = 4.5 + 4.5 + 37 + 4.33 + 4.17 + 12.17 = 66.67 feet

$$= 500\left[\frac{L * N}{N - 1} + 12 * N + 36\right]$$

$$= 500\left[\frac{66.67 * 7}{7 - 1} + 12 * 7 + 36\right]$$

W (max weight) = 98,890.83 lbs.

Equiv. Factor = W(actual)/W(max) = 142,000/98,890.83 = 1.436

Maximum Equivalency Factor

The maximum equivalency factor calculated for the permit vehicle is **1.558** for the axle 2-4 combination grouping. The 1.558 Equivalency Factor will be used for the HS20 Operating Rating and Permit Analysis Rating comparisons.

Appendix 3-4 – Permit Analysis Examples

The permit vehicle used in Appendix 3-3 will be analyzed for a group of bridges. The QPermit output below illustrates how the calculated Equivalency Factors are displayed.

BRIDGE MANAGEMENT OVERLOAD PERMIT REPORT

Report Date :10/5/2020
Permit Date : 10/7/2020

Permit Number : 000EK201005001

Permittee : A DEL CONSTRUCTION INC **Name Code :** 000EK

Origin : 703 HARVEY RDCLAYMONT, DE

Destination : US 301 DE/MD LINE ANNAPOLIS, MD

Vehicle Ht (ft) : 13'-6" **Gross Weight (kips) :** 142.00

Axle Number	Axle Weight (Kips)	Axle Spacing(ft)	HS20 Equivalent Factor	Controlling
1	13.000	12.17	0.781	Axle 3 of 25000 lb or Axle 4 of 25000 lb
2	16.000	4.17	1.456	Axle 3 of 25000 lb, Axle 4 of 25000 lb
3	25.000	4.33	1.558	Axle 2 of 16000 lb, Axle 3 of 25000 lb, Axle 4 of 25000 lb
4	25.000	37.00	1.416	Axle 1 of 13000 lb, Axle 2 of 16000 lb, Axle 3 of 25000 lb, Axle 4 of 25000 lb
5	21.000	4.50	1.422	Axle 3 of 25000 lb, Axle 4 of 25000 lb, Axle 5 of 21000 lb, Axle 6 of 21000 lb, Axle 7 of 21000 lb
6	21.000	4.50	1.488	Axle 2 of 16000 lb, Axle 3 of 25000 lb, Axle 4 of 25000 lb, Axle 5 of 21000 lb, Axle 6 of 21000 lb, Axle 7 of 21000 lb
7	21.000	0.00	1.436	Axle 1 of 13000 lb, Axle 2 of 16000 lb, Axle 3 of 25000 lb, Axle 4 of 25000 lb, Axle 5 of 21000 lb, Axle 6 of 21000 lb, Axle 7 of 21000 lb.

BRIDGE	VERT. CLEARANCE	ANALYSIS RESULTS
1044 214	Not Checked	Controlling EF = 1.558 Single with Traffic EF = 1.875 Permit vehicle can proceed on bridge without any restrictions.
1442 457	Not Checked	Controlling EF = 1.558 Single with Traffic EF = 1.733 Permit vehicle can proceed on bridge without any restrictions.
1555 356	Not Checked	Controlling EF = 1.558 Single with Traffic EF = 1.640 Permit vehicle can proceed on bridge without any restrictions.
1052 023	Not Checked	Controlling EF = 1.558 Single No Traffic EF = 1.672 Permit vehicle can proceed without any other vehicles on bridge while crossing
1047 000	Not Checked	Controlling EF = 1.558 Single With Traffic No Impact EF = 1.649 Permit vehicle can proceed with 10 mph speed on bridge while crossing
1406 430	Not Checked	Controlling EF = 1.558 Single No Traffic No Impact EF = 1.632 Permit vehicle can proceed with 10 mph speed and no other vehicles while crossing bridge
1568 311	Not Checked	Controlling EF = 1.558 Single No Traffic No Impact EF = 1.364 Permit will be sent to Bridge Management for engineer review. A BRASS Analysis may be required for permit vehicle crossing bridge

The table below shows the permit analysis fields obtained from the DelDOT Load Ratings page in the Inspection module in BrM.

Single Trip Permit Analysis

Starting with the single trip / mixed with traffic load factor, QPermit will review the data shown in the chart below to find a load factor which is greater than the maximum equivalency factor by following the chart left to right. The restriction associated with the first load factor that exceeds the maximum equivalency factor will be reported in QPermit and entered as a restriction into the special provision text field of the permit by the reviewer. The yellow highlighted values indicate the rating factor for each bridge that first exceed the calculated Equivalency Factor of 1.558.

Bridge Number	HS20 Operating Rating	Unlimited Crossings	Single Trip/Mix with Traffic	Single Trip/No Traffic	Single Trip/Mix with Traffic/No Impact	Single Trip/No Traffic/No Impact	Bridge Length (ft)	Max Span Length (ft)
1044 214	1.67	1.73	1.88	2.05	2.49	2.72	64.3	19.4
1442 457	1.54	1.60	1.73	1.89	2.30	2.51	12.0	12.0
1555 356	1.46	1.51	1.64	1.79	2.18	2.38	398.8	150.0
1052 023	1.36	1.41	1.53	1.67	2.04	2.22	18.0	18.0
1047 000	1.10	1.14	1.24	1.35	1.65	1.80	16.0	16.0
1406 430	1.00	1.04	1.13	1.23	1.50	1.63	49.0	14.2
1568 311	1.11	1.15	1.25	1.36	1.25	1.36	13.0	8.0

The analysis process is illustrated in the following examples for single trip permit analysis.

- Example 1: Permit vehicle has an Equivalency Factor of 1.56. For bridge 1044 214, since the 1.56 Equivalency Factor is less than 1.88 for the case of the Single Trip/Mix with Traffic. Select this case. **Permit vehicle can proceed on bridge without any restrictions.**
- Example 2: Permit vehicle has an Equivalency Factor of 1.56. For bridge 1442 457, since the 1.56 Equivalency Factor is less than 1.73 for the case of the Single Trip/Mix with Traffic. Select this case. **Permit vehicle can proceed on bridge without any restrictions.**
- Example 3: Permit vehicle has an Equivalency Factor of 1.56. For bridge 1555 356, since the 1.56 Equivalency Factor is less than 1.64 for the case of the Single Trip/Mix with Traffic. Select this case. **Permit vehicle can proceed on bridge without any restrictions.**
- Example 4: Permit vehicle has an Equivalency Factor of 1.56. For bridge 1052 023, since the 1.56 Equivalency Factor is less than 1.67 for the case of the Single Trip/No Traffic. Select this case. **Permit vehicle can proceed on bridge without any other vehicles on bridge while crossing for a single trip.**
- Example 5: Permit vehicle has an Equivalency Factor of 1.56. For bridge 1047 000, since the 1.56 Equivalency Factor is less than 1.59 for the case of the Single Trip/Mix with Traffic/No Impact. Select this case. **Permit vehicle can proceed with 10mph speed on bridge while crossing for a single trip.**
- Example 6: Permit vehicle has an Equivalency Factor of 1.56. For bridge 1406 430, since the 1.56 Equivalency Factor is less than 1.63 for the case of the Single Trip/No Traffic/No Impact. Select this case. **Permit vehicle can proceed with 10mph speed and no other vehicles while crossing bridge for a single trip.**
- Example 7: Permit vehicle has an Equivalency Factor of 1.56. For bridge 1568 311, since the 1.56 Equivalency Factor is greater than 1.36 for the case of the Single Trip/No Traffic/No Impact. Select this case. **Permit will be sent to Bridge Management for engineer review. A BRASS Analysis may be required for permit vehicle crossing bridge.**