Guidelines for Determining Load Capacity Ratings through Engineering Judgment

Due to a recent directive from the FHWA to establish load ratings for every structure within the State of New Jersey, it is imperative to maintain the balance between the bridge safety and the ability to allow overweight permit vehicles to use the structure. In order to create a uniform method for assigning load capacity ratings to existing in service structures through the use of Engineering Judgment, this document will serve as the established practice and resource necessary to best estimate an accurate load rating set of values for the existing structures, where actual load ratings cannot be performed due to missing bridge plans or for other valid reasons.

This document contains **two different approaches for load rating bridges using engineering judgement**. The first approach should be used for Concrete Encased Steel bridges, Reinforced Concrete bridges, Pre-stressed Concrete bridges and Stone Masonry bridges **where plans are not available**. If the first approach is used, then Items 63 and 65 in SI&A should be coded as zero (0) for “Engineering Judgement".

The second approach is from the FHWA and applies to the bridges where plans are available and satisfy five specific conditions, as described later in this document. If the second approach is used, then Items 63 and 65 in SI&A should be coded A thru F, as appropriate for "Assigned Load Ratings". For additional guidance, refer to NJDOT Bureau of Structural Evaluation memorandum dated January 13, 2017.

As per the latest edition of Manual of Bridge Evaluation, Section 6A.5.8, we are not required to perform the load ratings for shear for reinforced and pre-stressed concrete type bridge members for as built condition. Hence for these members, load ratings will be performed for **moment only** for as built condition.

FIRST APPROACH:

DESIGN YEAR	DESIGN VEHICLE	RATING METHOD
< 1944	H20	Engineering Judgment
1944 – 2000	HS20	Engineering Judgment
2000 – PRESENT	HL93	Engineering Judgment

Table 1: Rating Method and Design Load based on the Year of Construction

The above table should serve as a reference for determining the design load.

When load rating any structure that is not owned by the State, please verify the validity of above table with the bridge owner.

Incomplete plans are often cited as a cause for a Load Rating Engineer's inability to use commercial software in obtaining load rating results. The following two conditions should be evaluated, as necessary, in order to obtain load rating results:

1. If the plans are incomplete and don't provide necessary information, or if plans are unavailable for a particular structure, use the procedure mentioned in this document.

2. Please use Table 1 if plans do not list the Design Load.

Procedure for Load Rating Calculations through the use of Engineering Judgment

A. As Built Ratings

1. Using Table 1, identify the appropriate Design Load for the structure. By referring to MBE and AASHTO Standard Specifications tables, evaluate the Live Load Moment for given span length for the bridge. By performing simple calculations, obtain the Live Load Shear force for given span length for the bridge (*).
2. Assume inventory rating factor for the chosen Design Load is equal to 1.0.
3. From MBE and NJDOT Design Manual, evaluate the live load moment for AASHTO trucks 3, 3-3, SHV-4, SHV-5, SHV-6, SHV-7 and NJ3S2. By performing simple calculations, obtain the Live Load Shear force for the trucks mentioned as above (*).
4. If the chosen Design Load is not HL93, compute the inventory rating for the Design Load in tons by multiplying the rating factor, 1.0 with the weight of the Design Vehicle.
5. Use the following equation to calculate the inventory rating values (as built condition), in tons, for both moment and shear ratings of the following Legal Trucks, AASHTO trucks 3, 3-3, SHV-4, SHV-5, SHV-6, SHV-7 and NJ3S2:

$$\frac{LL_{Design\ Load}}{LL_{Rating\ Truck}} * Weight_{Rating\ Truck}$$

Equation 1: Load Rating Calculation through the use of Engineering Judgment in LFR

Where:

$$LL_{Design\ Load} = Live\ Load\ Moment/Shear\ for\ the\ Design\ Load\ (Includes\ Impact)$$

$$LL_{Rating\ Truck} = Live\ Load\ Moment/Shear\ for\ the\ Truck\ being\ rated\ (Includes\ Impact)$$

$$Weight\ (Tons)_{Rating\ Truck} = Weight\ of\ the\ Truck\ being\ rated\ (Tons)$$

6. Compare the moment and shear rating values for each truck and choose the lower rating value as the controlling rating for the truck.

7. Use the following equation to convert between Inventory and Operating Rating to complete the Load rating:

$$Rating\ Factor_{Oper} = 1.67 * Rating\ Factor_{Inv}$$

Equation 2: Conversion between Inventory and Operating Ratings in LFR

8. If the chosen Design Load is HL93, the inventory rating for the design load is 1.0 and operating rating is 1.75/1.35 = 1.3
9. Use the following equation to calculate the posting rating values (as built condition) for both moment and shear for the posting ratings of the following Legal Trucks, AASHTO trucks 3, 3-3, SHV-4,SHV-5,SHV-6, SHV-7 and NJ3S2 :

$$\frac{\gamma 1(for\ LL_{Design\ Load}\ )X\ Inventory\ R.F.\ \ for\ HL-93}{\gamma 2\ (for\ LL_{Rating\ Truck})}$$

Equation 3: Load Rating Calculation through the use of Engineering Judgment in LRFR

Where: $\gamma 1 = Live\ Load\ Factor\ given\ in\ MBE\ Table\ A.4.3.2.2-1\ for\ Design\ Load\ HL93 = 1.75$

$\gamma 2 = Generalized\ Live\ Load\ Factor\ given\ in\ MBE\ Table\ A.4.4.2.3a-1$

$for\ Routine\ Commercial\ Traffic, and\ in\ MBE\ Table\ A.4.4.2.3b-1 for\ SHVs$

Choose the lower rating value between moment and shear as the posting rating for the truck.

(*) indicates the following:

Shear ratings for As-Built condition are needed for Concrete Encased Steel and Stone Masonry bridges only.

As Inspected Ratings:

1. **Concrete Encased Steel Bridges** – If significant deterioration was observed in concrete encasement near the mid-span or at the beam ends during the inspection, it is NJDOT's policy to remove the encasement to perform hands on inspection of underlying steel member to observe any corrosion and section loss. At this time, the bridge Inspection Team Leader needs to take the measurements for the remaining steel section to load rate the bridge, using remaining section details.

2. **Reinforced Concrete and Pre-stressed Concrete Bridges –** For these types of bridges, if a defect coding **o**f exposed rebars/strands near mid-span and support are chosen under National Bridge Element guidelines, only then as inspected ratings will be performed. If the exposed rebars/strands are stated to be in NBE condition state 2, then the inventory rating factor as inspected condition will be equal to the inventory rating factor as built condition times 0.95. If in condition state 3, the multiplication factor will be 0.85 instead of 0.95. For condition state 4, we are waiting for an approach from Rutgers University's Bridge Resource Program (BRP).

3. **Stone Masonry Bridges –** This pertains to arches which in general have significant fill and hence much reduced intensity of live load. The as built ratings are therefore pretty conservative for this type of bridge. If a significant distress or heavy deterioration is observed during inspection, only then as inspected ratings will be performed for the stone masonry arches. We are waiting for an approach to perform as inspected ratings from Rutgers University's Bridge Resource Program (BRP).

SECOND APPROACH:

Procedure for Calculating Load Rating through the use of Assigned Load Ratings

In order to evaluate structures designed after 1993, it is FHWA policy to allow the use of Assigned Load Ratings as per the Second Edition of the Manual for Bridge Evaluation. In order to use the Assigned Load Rating philosophy, the following five conditions must be met for each structure:

(1) The bridge was designed and checked using either the AASHTO Load and Resistance Factor Design (LRFD) or Load Factor Design (LFD) methods to at least HL-93 or HS-20 live loads, respectively; and
(2) The bridge was built in accordance with the design plans; and
(3) No changes to the loading conditions or the structure condition have occurred that could reduce the inventory rating below the design load level; and
(4) An evaluation has been completed and documented, determining that the force effects from State legal loads or permit loads do not exceed those from the design load; and
(5) The checked design calculations, and relevant computer input and output information, must be accessible and referenced or included in the individual bridge records.

If all of the above five conditions are documented in the bridge file, and reviewed and approved by the Load Rating Engineer, the following procedure can be used to calculate Assigned Load Rating values.

1. Obtain the design calculations and all plans that are available for the structure.
2. From the design calculations, obtain the Dead Load Moment/Shear (*) and the Capacity for the superstructure element.
3. Calculate the Live Load moment/Shear (*) based on the Design Load for the structure.
4. Use the following equation for inventory load rating through the use of Assigned Load Rating for the Design Loads and each of the Legal Loads for both moment and shear (*) :

$$\frac{C - DL}{LL_{LL+IMP}} = Rating\ Factor_{Inv}$$

Equation 4: General Equation for load rating using Assigned Load Rating Philosophy

Where:

$$C = Capacity$$

$$DL = Dead\ Load\ Moment/Shear$$

$$LL_{LL+IMP} = Live\ Load\ Moment\ /\ Shear\ (Including\ Impact)$$

5. Choose the lower rating value between moment and shear as the controlling Inventory rating for the truck.

6. If the Design Load is HS20, then multiply the Rating Factor by the Weight of the Truck being rated (Tons).

7. Use the following equation to obtain the Operating Ratings, if the bridge is designed with LFD:

$$Rating\ Factor_{Oper} = 1.67 * \ Rating\ Factor_{Inv}$$

Equation 5: Conversion between Inventory and Operating Ratings for LFD

8. If the chosen Design Load is HL93, calculate operating rating as (1.75/1.35)* controlling Inventory Rating Factor obtained from step 5.

9. Use the following equation to calculate the posting rating values (as built condition) for both moment and shear for the posting ratings of the following Legal Trucks, AASHTO trucks 3, 3-3, SHV-4,SHV-5,SHV-6, SHV-7 and NJ3S2 :

$$\frac{\gamma 1(for\ LL_{Design\ Load}\ ) * \ \ R.F.\ for\ HL - 93\ (Step\ 5)}{\gamma 2\ (for\ LL_{Rating\ Truck})}$$

Equation 3: Load Rating Calculation through the use of Engineering Judgment in LRFR

$$Where: \gamma 1 = Live\ Load\ Factor\ given\ in\ MBE\ Table\ A.4.3.2.2 - 1\ for\ Design\ Load\ HL93 = 1.75$$

$$\gamma 2 = Generalized\ Live\ Load\ Factor\ given\ in\ MBE\ Table\ A.4.4.2.3a - 1$$

$$for\ Routine\ Commercial\ Traffic, and\ in\ MBE\ Table\ A.4.4.2.3b - 1 for\ SHVs$$

Equation 6: Conversion between Inventory and Operating Ratings for LRFD

(*) indicates the following:

Shear rating for As-Built condition is needed for Concrete Encased Steel and Stone Masonry bridges only.