

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 Judgement, 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.

The approaches presented in this document should not be used if the following conditions are present:

1. Depth of the fill is more than 8' and Design load is not HL-93.
2. Depth of the fill is more than 8' and more than the span length. The Design load is HL-93.

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**. This approach can also be used for Circular, Elliptical & Parabolic Flexible and Rigid Culverts. For flexible culverts this approach should be used only when the culverts cannot be inspected due to lack of access because of debris accumulation or other reasons. 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. This approach cannot be used for the flexible and rigid culverts. 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 June 26, 2015 and revised 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.

Please **verify** with the bridge owner, the validity of the above table while rating bridges other than state owned bridges.

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. If the plans do not list the Design Load, please use Table 1.

Procedure for Load Rating Calculations through the use of Engineering Judgment

A. As Built Ratings

a. (For Bridges other than Culverts)

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 for both moment and shear.
3. From MBE and NJDOT Design Manual, evaluate the live load moment for other design loads (H-20 or HS-20), 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 and the Live Load Bending Moment and Shear Force for Emergency Vehicles EV2 and EV3.
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 for other design loads (H-20 or HS-20), AASHTO trucks 3, 3-3, SHV-4, SHV-5, SHV-6, SHV-7, NJ3S2 and emergency vehicles EV2, EV3:

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

Equation 1: Load Rating Calculation through the use of Engineering Judgment in LFR For Bridges Other than Culverts

Where:

B = Multiplication Factor to As Built Ratings for As Inspected Conditions

= 1.00 for As Built Ratings

= 0.95, 0.85 for As Inspected Ratings

LL_{Design Load} = Live Load Moment/Shear for the Design Load

LL_{Rating Truck} = Live Load Moment/Shear for the Truck being rated

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.

- 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

- If the chosen Design Load is HL93, the inventory rating for the design load is 1.0 for moment and shear in as-built conditions and 0.95, 0.85 in as inspected conditions. The operating rating is $1.75/1.35 = 1.3$ times the as built rating.
- Use the following equation to calculate the posting rating values (as built condition) for both moment and shear for the posting ratings of AASHTO trucks 3, 3-3, SHV-4,SHV-5,SHV-6, SHV-7 and NJ3S2 and emergency vehicles EV2, EV3:

$$\frac{\gamma_1(\text{for } LL_{Design Load}) \times \text{Inventory R.F. for HL - 93}}{\gamma_2(\text{for } LL_{Rating Truck})}$$

Equation 3: Load Rating Calculation through the use of Engineering Judgment in LRFR for Bridges Other than Culverts

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,

given in MBE Table A.4.4.2.3b – 1 for SHVs

Live Load Factor for Emergency Vehicles, EV2 & EV3 = 1.3

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

b. (For Flexible & Rigid Culverts)

- Using the existing plans and documents or Table 1 as explained above, identify the appropriate Design Load for the structure.
- Assume inventory rating factor for the chosen Design Load is equal to 1.0.
- 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.
- Use the following equation to calculate the inventory rating values (as built condition), in tons for the other design loads (H-20 or HS-20), AASHTO trucks 3, 3-3, SHV-4,SHV-5,SHV-6, SHV-7 and NJ3S2 and emergency vehicles EV2, EV3:

$$A * Weight_{Rating Truck}$$

Equation 4: Load Rating Calculation through the use of Engineering Judgment in LFR for Flexible and Rigid Culverts

Where:

$$A = \frac{\text{(Maxm sum of adjacent axle loads in Design Truck H20 or HS20 or HL – 93 in the span)}}{\text{(Maximum of Sum of adjacent axle loads in Truck being rated in the span)}}$$

In computing the “A” value, ignore the lane load

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

4. Use the equation no.2 to convert the Inventory rating to Operating Rating to complete the Load rating for all live loads.
5. 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
6. Use the following equation to calculate the posting rating values (as built condition) for the posting ratings for AASHTO trucks 3, 3-3, SHV-4,SHV-5,SHV-6, SHV-7 and NJ3S2 and emergency vehicles EV2, EV3:

$$A * \frac{\gamma_1(\text{for } LL_{Design Load})}{\gamma_2(\text{for } LL_{Rating Truck})}$$

Equation 5: Load Rating Calculation through the use of Engineering Judgment in LRFR for Flexible and Rigid Culverts

Where: $\gamma_1 = \text{Live Load Factor given in MBE Table A. 4.3.2.2 – 1}$

for Design Load HL93 = 1.75,

$\gamma_2 = \text{Generalized Live Load Factor given in MBE Table A. 4.4.2.3a – 1}$

*for Routine Commercial Traffic,
given in MBE Table A. 4.4.2.3b – 1 for SHVs*

Live Load Factor for Emergency Vehicles, EV2 & EV3 = 1.3

B. As Inspected Ratings:

a. (For Bridges other than Culverts)

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. In the hands on inspection, 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 of exposed rebars/strands near mid-span 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 for the Design Load 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 will use an approach from Rutgers University's Bridge Resource Program (BRP). Follow the As Built Ratings Guidance (Equation 1) for other trucks eg., Legal Trucks, SHVs and EVs.

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 will use an approach to perform as inspected ratings from Rutgers University's Bridge Resource Program (BRP).

b. (For Flexible & Rigid Culverts)

This pertains to culverts 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 bridges. If during inspection, an inspector finds significant distress (eg., for flexible culverts: multiple local buckling/ global buckling/section loss/etc and for rigid culverts: significant cracking/spalls in concrete, section losses in exposed rebars/strands/etc.,) than the team leader will recommend either retrofitting/rehabilitating the structure or replace the structure based on the extent of the distress in his findings.

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 effects as described in the first approach.
4. Use the following equation for inventory load rating for the Design Load and AASHTO trucks 3, 3-3, SHV-4, SHV-5, SHV-6, SHV-7 and NJ3S2 and emergency vehicles EV2, EV3:

$$\frac{C - DL}{LL_{LL+IMP}} = \text{Rating Factor}_{Inv}$$

Equation 6: General Equation for load rating using Assigned Load Rating Philosophy

Where:

$C = \text{Capacity}$

$DL = \text{Dead Load Moment/Shear}$

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

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 equation no.2 to convert the Inventory rating to Operating Rating to complete the Load rating for all the live loads.
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 Equation 3 to calculate the posting rating values (as built condition) for both moment and shear for AASHTO trucks 3, 3-3, SHV-4, SHV-5, SHV-6, SHV-7 and NJ3S2 and emergency vehicles EV2, EV3.