Where's the Guidance?

An Interim Approach for Load Rating Culverts and Flexible Buried Bridges

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Joel Hahm, P.E.
Senior Engineer
Big R Bridge
Greeley, CO
jhahm@bigrbridge.com
www.bigrbridge.com

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Presentation Outline

- Current Practices for load rating buried structures
- Differences to consider in load rating bridges vs. buried structures
- Proposed interim approach

Current Load Rating Practices

Definitions per AASHTO LRFD Manual for Bridge Evaluation (MBE):

Load Rating: Determination of live load capacity of an existing bridge.

Inventory Rating: Load that can safely use a bridge for an indefinite period of time.

Operating Rating: Maximum permissible live load that can be placed on the bridge. Can shorten bridge life if applied on a routine basis.

Rating Factor: Factor for live load capacity. Theoretically, multiply design load by rating factor for that load to determine regular live load capacity.

Posting: Load restriction on a bridge.

Current Load Rating Practices

State of the Industry:

- NO current AASHTO specification for load rating of culverts or buried structures (only flat topped concrete boxes addressed in MBE)
- Many states reference the MBE only with no specific guidance
- A few states reference the MBE and also include some guidance and in some cases (OH, MI) tools to assist
- A few consultants have developed in-house tools or adapted tools from other states
- Some manufacturers have in-house tools & methods
- NCSPA Design Data Sheet 19 (developed in 1995) is a common reference and still used to some degree in some areas.
- **No commonly accepted or applied approach**

Current Load Rating Practices

Typical Approaches for Load Rating Buried Structures:

- Punt - “Do whatever you feels is appropriate”
- Attempt to apply bridge load rating principles
- Little to no consideration for soil-structure interaction, geometry, backfill materials, usage
- Often results in unrealistically high or low rating factors
- Rating Factors applied to GVW to obtain Load Rating – irrelevant to actual live load capacity of buried structure.
- Incremental loading approach

Current Load Rating Practices

MBE Update from AASHTO SCOBS Meeting (April 2015):

- Added to Article 6B.7.1 (paraphrased): If a concrete culvert with 2' minimum cover is performing satisfactorily and is in fair or better condition (as determined by qualified inspector), an Inventory Rating Factor of 1.0 and Operating Rating Factor of 1.67 for HS20 loading can be used and posting is not necessary.

- Article C6B.7.1 added commentary acknowledging that soil-structure interaction is neglected when determining load ratings, resulting in satisfactory performance while analytical ratings indicate insufficient capacity.

- Background to the ballot mentioned recent changes in design standards that introduced conservatism compared to past standards, which have contributed to low analytical ratings as well as existence of anecdotal evidence of satisfactory performance of old culverts to support the ballot.

- Only in LFR section (considered in LRFR with $RF_O = 1.3$ but did ballot did not pass).

- Why not apply to all culvert types? Culvert performance typically has more to do with site & installation factors than material type.

Differences in Load Rating Bridges vs. Buried Structures

- Magnitude of live load with buried structures diminishes significantly away from crown
  - Effect of load decreases with cover and lateral distance of load from crown
  - Full load is felt on bridge – felt as more of a moment at mid span, shear near supports

- Many factors, complications, scenarios, etc. need to be considered for bridges
  - Worst case with buried structures is almost always when heaviest axle is at the crown / point of lowest cover
  - Worst case on a bridge could be anywhere and in any configuration.
  - No need for evaluation of live load capacity to be as complicated for buried structures as it is for bridges

- Minimal effect on buried structures from multiple axles
  - Governed by heaviest axle at crown – axles away from crown have minimal effect
  - Depending on bridge span all axles could exist in any configuration on bridge.

Differences in Load Rating Bridges vs. Buried Structures

- Gross Vehicle Weight (GVW) is not relevant for buried structures
  - Effect will depend more on axle loads and groupings relative to position with crown
  - More critical for bridge, where entire vehicle could be on the bridge

- On medium to large span arches (generally ~45’ + span) & large diameter culverts peaking will govern design
  - Peaking is upward movement & stresses in crown during backfilling. Stresses decrease as fill is placed above crown.
  - In some structures peaking stresses remain in structure and are cancelled out during application of live load - resulting in no net forces in structure. Actual live load capacity could be much higher than what was designed for.
  - In bridges, loads are either there or they aren’t.

Differences Between Design and Rating

- **Design: Structure properties and capacities are known and there is some level of uncertainty in the amount of loading over the service life of the structure.**
- **Rating: Loading conditions are known and there is some level of uncertainty in the structure properties and capacities.**
- **Review MBE Section C6A.1.1 for perspective on load rating.**
  - **Level of detail & analysis in a designed & checked structure is much more comprehensive than a load rating.**
  - **Base rating on design loading.**
  - **No load rating calculations required for structures designed per AASHTO LRFD with HL93 design live load.**

NCHRP 15-54

“Proposed Modifications to AASHTO Culvert Load Rating Specifications”

- Research Need Statement developed by members of TRB standing subcommittees AFS40 and AFF70. Intent was to study and develop a standard methodology for load rating culverts and buried bridges. Representatives from industry, consulting, researchers, and stakeholders collaborated on development of the scope of the study.
- Link to TRB Summary: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3869
- Awarded in July 2015
- Anticipated schedule ~ 2 ½ years + panel review time

Proposed Interim Approach for Rating Buried Structures

Main Goals

- Common Sense Application of Existing Methods
- Applicable to buried structures
- Simple

Proposed Interim Approach for Rating Buried Structures

Preparation for Load Rating an Existing Structure:

- Carry out a field inspection based on applicable procedures
- General site conditions
- Determine actual cover (critical for older structures)
- Shape measurements, material thickness, etc.
- Backfill type & condition
- Other relevant information

Proposed Interim Approach for Rating Buried Structures

Step 1:

Perform design check per AASHTO LRFD with HL93 design load.

- **If it is an older existing structure, base design on field observations & measurements**
- **If it is a newer existing structure (~5 yrs old or less), base design on original condition unless inspection indicates conditions have changed or it was not constructed according to plan.**
- **If design check confirms current AASHTO LRFD design standards are met, use Rf_i = 1.0 and Rf_o = 1.3.**
  - **Allowable in MBE per Section C6A.1.1**
  - **Rating good for all AASHTO Legal Loads**

Proposed Interim Approach for Rating Buried Structures

Step 2: (if design does not meet requirements in Step 1)

Calculate rating factor based controlling load case.

- RF calculation per MBE Equation 6A.4.2.1 using HL93 live load
- Based on governing load condition: wall area, seam strength, moment, etc. – whichever is controlling in design.
- If rating factors ≥ 1.0, use calculated Rf_i and Rf_o.
  - Design load rating procedure as in MBE 6A.4.3

Proposed Interim Approach for Rating Buried Structures

Step 3: (if RF<1.0 in Step 2)

Check AASHTO legal loads.

- Determine governing vehicle / load configuration and calculate RF based on design load rating (Step 2)
- Multiply RF by axle design load to obtain rating load (max axle loading).
- Do not apply RF to GVW.
  - Legal load rating procedure as in MBE 6A.4.4

Proposed Interim Approach for Rating Buried Structures

Step 4: (if RF<1.0 in Step 3)

Higher level analysis to obtain rating *or* evaluate for posting.

- **Look at more detailed analysis methods & inspection (physical testing, soil data, finite element analysis, etc.) and recalculate with more accurate data.**

OR

- **Use an iterative approach to determine maximum axle load to obtain Rf_i = 1.0 and use that axle load for posting.**
- **Posting should be based on maximum axle loading rather than GVW.**

Proposed Interim Approach for Rating Buried Structures

Additional Comments

- No additional analysis / design should be needed for special vehicles or permit loads unless axle loading exceeds design axle load.
- Permit load rating uses same procedure as legal load rating but with different live load factors.
- GVW is not an appropriate measure for Load Rating of a buried structure. Load Rating should be based on axle loading or grouping (i.e. xx kip single axle / xx kip tandem axle, etc.).

Thank You!

Joel Hahm, P.E.
Big R Bridge
970-347-2208
jhahm@bigrbridge.com
www.bigrbridge.com

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