JOINT TRANSPORTATION RESEARCH PROGRAM

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Use of LRFR Methodology for Load Rating of INDOT Steel Bridges

Introduction

A method for examining the load carrying capacity of a structure is Bridge Load Rating. It is a process of determining the structural condition and safety of a bridge. Load rating typically utilizes bridge information obtained from the plans, design calculations, or field information to conduct a structural analysis and evaluation to determine if the bridge is safe for public use.

The current preferred methodology used for load rating is Load and Resistance Factor Rating (LRFR). Before LRFR, load rating was carried out by using either Load Factor Rating (LFR) or Allowable Stress Rating (ASR) methods. The American Association of State Highway and Transportation Officials (AASHTO) developed a powerful software called AASHTOWare Bridge Rating (BrR). The software is compliant with the *LRFD Bridge Design Specifications*. Today, many of the State Departments of Transportation (DOTs) use this software to carry out comprehensive load ratings of structures.

Continuous dual plate girder bridge on US 41 over the White River.

The Indiana Department of Transportation (INDOT) expressed a desire to use just one load rating method (LRFR). Although the shift from LFR to LRFR over the years has ensured more consistent decisions regarding the safety of bridges, there are some shortcomings. It was observed that LFR and LRFR methodologies produced different rating factors for the same structure. INDOT has reported that in some bridges AASHTOWare BrR indicated a bridge was satisfactory for LFR (RF > 1) but not adequate for LRFR (RF < 1). These bridges belonged to a few different limit states: lateral torsional buckling, changes in the cross section along the mem-ber length, tight stringer spacing, girder end shear, and moment over continuous piers.

Findings

The limit states discussed earlier were examined for select bridges that generally satisfied LFR rating but were inadequate for LRFR evaluation. LRFR was found to be appropriate for most applications. However, for a few limited situations, recommendations were suggested for adapting the AASHTOWare BrR for LRFR with modification to the input information.

For the limit state of lateral torsional buckling, the calculation of the moment gradient modifier, C_b for all non-prismatic sections, is assumed to be equal to 1.0, which is a conservative approach. To rectify this, a new method to calculate C_b is suggested for stepped beams (or non-prismatic sections).

Another recommendation concerned the modelling of tapered, partial length cover plates in AASHTOWare BrR. AASHTOWare BrR uses a conservative approach to calculate the effective width of tapered cover plates.

Instead, a new approach based on the principles of direct proportion of the width within the length in which it occurs is used.

For tight stringer spacings, it was observed that the controlling factor for the resulting lower rating factor values by LRFR was the calculation of the live load distribution factors. The formulae in the *LRFD Bridge Design Specifications* (AASHTO, 2020) that calculate LL distributions can be used only if the girder characteristics fall in the range of applicability. If not, then the lever rule is used to calculate the LL distributions—this approach is based on statics and often produces higher than anticipated LL distribution factors (LLDF). This results in higher live load effects and lower rating factors. To improve the results produced by lever rule, use of a technique called Henry's method is suggested to calculate moment LLDF for stringers with tight spacings (less than 3.5 ft.).

The final limit state addressed was girder end shears and moment over continuous piers. For this limit state, the 14 bridges that were examined earlier for lateral torsional buckling earlier, along with two additional bridges, were reviewed. It was observed that apart from two bridges, all the other bridges were adequate for shear. These two bridges showed an abnormal spike in the shear values within the length of the girder; therefore, it is believed that the modeling and analysis of the girders in AASHTOWare BrR was flawed. The bridges that were inspected earlier for lateral torsional buckling for flexure, pass for this limit state as well if the recommendations presented earlier are adopted.

It was observed that the AASHTOWare BrR software generally works well and, other than the possible changes noted in this study, the BrR results should be used. The recommendations suggested in this study can be adopted by INDOT to resolve the problem of inadequacy of bridges by LRFR methodology.

Implementation

AASHTOWare BrR was used extensively to examine the input information for problematic cases. The results from AASHTOWare BrR were compared with the results of detailed Mathcad and SAP2000 analysis. It was concluded that the analysis and capacity calculations conducted by AASHTOWare BrR are according to the provisions of the *LRFD Bridge Design Specifications*. It was observed that there are modifications that can be incorporated into the BrR software input data to provide more accurate results for problematic limit states of bridges designed by LFD. These modifications involve three specific situations.

1. The capacity in BrR can be modified using the "Capacity Override" feature to input the value obtained from using a new C_b for non-prismatic sections.
2. Tapered cover plates can be modelled as a rectangular cover plate by using a new proposed equation for the effective width. The revised width can be manually entered in the BrR software. BrR uses this new cover plate geometry to calculate a new LTB capacity, and thus a new rating factor is generated.
3. For tight stringer spacings less than 3.5 feet, the live load distribution factor computed by Henry's method can be used in BrR by the user inserting the new value. This new value is then used by BrR to compute new moment live load effects, and hence a new rating factor.

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