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Load Rating of Existing Continuous Stringers on Louisiana's Bridges

INTRODUCTION

Some of Louisiana's bridges built in the 1950s and 1960s used two-girder or truss systems in which floorbeams are carried by main members and continuous (spliced) stringers are supported by the floorbeams. The main members are either two edge (fascia) girders or trusses. When the continuous stringers are load-rated using AASHTOWare Bridge Rating™ (BrR) analysis software, C_b is calculated in accordance with the *AASHTO LRFD Bridge Design Specifications*, which does not account for the bracing effect of noncomposite deck properly and therefore underestimates the flexural strength. As a result, the rating may become low enough to require restrictive load posting or even closure. This issue affects bridges that are key parts of Louisiana's highway system. The current load rating would cause expensive (and possibly unnecessary) bridge rehabilitation or replacement with significant disruption for the traveling public. This project reassesses the methodology behind load rating the stringers, with efforts focusing on more realistic values for C_b.

OBJECTIVE

The project objective was to evaluate the bending capacity of continuous stringers in two-girder or truss structures and develop a new approach for load rating these stringers. This project focused on determining a reasonable, but not overly conservative, estimate of the moment gradient factor, C_b.

SCOPE

The project scope consisted of three major tasks. The first task focused on the review of domestic and international guidelines and specifications and research studies on how to realistically determine the lateral torsional buckling (LTB) strength of continuous stringers by using a reasonable moment gradient factor, C_b. The focus was on doubly-symmetric stringer sections primarily subject to vertical loading. In the second task, current procedures related to load rating continuous stringers on floorbeams were studied. The third, primary, task intended to develop a methodology to determine a more realistic moment gradient factor. This task included lab tests that approximated behavior of stringers in a bridge while accounting for various types of bracings. Finite element analyses were conducted to simulate the behavior of the tested stringers. A couple of representative bridges were also analyzed using finite element models to evaluate the stringers' flexural strengths.

METHODOLOGY

This project included an experimental study of the LTB resistance of a two-span continuous steel structure, which included three lines of stringers, steel diaphragms at the end supports, and a floorbeam as the interior support. A variety of lateral bracing conditions were evaluated, including steel diaphragms, timber ties located at the stringer top flanges, and a noncomposite concrete deck. The steel diaphragms and timber ties were provided at variable spacings to investigate their bracing effects. To address variations in relative flexural stiffness where stringers were supported by a floorbeam, tests accounted for both rigid and flexible floorbeams. To account for connection restraint at the interior support, stringer bottom flanges were either unbolted or bolted to the floorbeams. The interior stringer was subject to a vertical point load at its midspan of either one or both spans. LTB resistance of the stringer from the lab testing was compared with predicted values in accordance with the *AASHTO LRFD Bridge Design Specifications*. The study also presented comparisons between moment gradient factors calculated from collected test data and those obtained from the existing specifications and codes.

Finite element analysis (FEA) simulated stringer behavior while accounting for various parameters, including geometric imperfections, various bracing configurations, rigid and flexible interior supports, other loading conditions, etc. A combination of static, linear Eigenvalue buckling, and non-linear buckling analyses were performed. Stringer geometry measurements were collected using laser scans prior to the tests.

CONCLUSIONS

Multiple lab tests were conducted to study the LTB resistance of continuous stringers with a noncomposite deck. The tests assessed the bracing effect of the deck and evaluated the effects due to the floorbeam relative stiffness and stringer-to-floorbeam connection conditions. The test results were analyzed to capture the axial, primary and out-of-plane bending, and warping torsion normal stress components. As a result, the experimental study can

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PRINCIPAL INVESTIGATOR:
Shawn Sun, Ph.D., P.E.

LTRC CONTACT:
Walid R. Alaywan, Ph.D., P.E.
225-767-9106

FUNDING:
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Louisiana Transportation Research Center

4101 Gourrier Ave
Baton Rouge, LA 70808-4443

www.ltrc.lsu.edu

justify use of a higher moment gradient factor than that taken from the *AASHTO LRFD Bridge Design Specifications* and increase the load rating factor for the continuous steel stringers. FEA models were calibrated to simulate stringer behavior while accounting for various parameters, including rigid and flexible interior (floorbeam) supports and various loading conditions. FEA can provide comparable results with the test data and reasonably predict the stringer flexural strength.

Based on the experimental study, the following conclusions can be drawn:

1. Testing data indicated friction occurred between the stringer and deck.
2. Lateral support provided by the deck was significant by comparing the experimental results to those tests without the deck.
3. When one span of the stringer was loaded, the unloaded span was subject to negative moment and stringers were unbraced. The critical stringer positive moment section for the noncomposite deck tests reached its yield or plastic moment capacity, while the critical negative moment section was shown to experience moment gradients best represented using C_b between 2.34 and 2.73.
4. When both spans were loaded, the interior stringer was predicted to eventually reach plastic moment at both critical negative and positive moment sections.

RECOMMENDATIONS

The following recommendations are provided for load rating of continuous stringers:

1. The positive moment section of a stringer was observed to be fully braced by the concrete deck. Therefore, the noncomposite plastic moment may be used for stringer nominal strength for load rating. The negative moment section, however, should account for LTB resistance subject to various loads. The stringer moment gradient factor can be determined using the equation proposed by Yura and Helwig (2010), which was also included in the Commentary C-F1-5 of the AISC Specification for Structural Steel Buildings (2016):

$$C_b = 3.0 - \frac{2}{3}\left(\frac{M_1}{M_0}\right) - \frac{8}{3}\left[\frac{M_{CL}}{(M_1+M_0)^*}\right]$$

2. It is recommended to use the full-span length as the unbraced length to determine the stringer's flexural strength regardless of whether the stringer bottom flange is braced by the floorbeam.
3. The bracing effect provided by the noncomposite deck was shown to significantly increase stringer LTB resistance, which results in a moment gradient factor appreciably larger than 1.0 and increases load rating factors. The moment gradient factor can be manually computed, and load rating factors refined for critical load cases should BrR not provide sufficient rating factors.
4. If the moment envelope approach due to HL-93 (Inventory) loads at the strength limit state results in unacceptable rating factors, C_b can be increased by 15% to take advantage of the concurrent moment approach unless a refined analysis is conducted.
5. Should the stinger be connected to a flexible floorbeam, it is conservative to conduct the load rating assuming a rigid interior support. If a refined analysis is necessary, the floorbeam can be modelled as a beam element to directly account for its flexural stiffness.