SPR RESEARCH PROGRAM
SECOND-STAGE PROPOSAL SUMMARY

PROBLEM NUMBER AND TITLE

24-23 New Methods for Improving Load Rating of Existing Steel Bridges.

PROBLEM SUMMARY

There are hundreds of steel bridges in Oregon that are in good condition and have performed well over extended lives. However, newly implemented rating checks for lateral-torsional buckling are now resulting in low rating factors that could require load posting for hundreds of bridges. Most of these steel bridges are simply supported steel stringers with either timber or corrugated metal decks and the bridges are located throughout the state. These bridges rated adequately using prior load rating methods, but recent updating of the load ratings using LRFR now produces very low rating factors for positive moment at mid-span. The main difference between the old and new methods is that lateral torsional buckling (LTB) controls the moment capacity and this was not checked in the old rating. There are cases where the rating factor is zero meaning the bridge cannot carry any truck load.

ODOT OBJECTIVES

The objectives of this research are to answer two questions. First, is it legitimate that lateral torsional buckling (LTB) should control the moment capacity for simply supported steel bridges that were never designed for this failure mode in the new LRFR load ratings? If so, then a clear explanation to bridge owners and the public is needed as to why this is so and why these bridges have not experienced such failures in practice. Second, given that LTB is a failure mode that is required to be checked in LRFR, is there some other mechanism acting in these older bridges that provides sufficient bracing to resist LTB and that has allowed them to perform so well in service for decades? If so, analysis and rating methods that account for this system mechanism in the load rating process is needed.

BENEFITS

A key component of safety is bridge load-rating that accurately reflects the controlling limits such as moment capacity in steel bridges that could be affected by lateral torsional buckling. Newly applied rating methods are now showing low load ratings for hundreds of Oregon bridges that are in good condition and carried loads for many years. By calculation, these bridges now require load-posting in many cases. More accurate bridge rating methods may produce outcomes that prevent bridges from being needlessly posted with low capacities. Bridge posting is contrary to ODOT's mission to connect people and help Oregon's communities and economy thrive.

SCHEDULE, BUDGET AND AGENCY SUPPORT

Estimated Project Length: 24 months.
Estimated Project Budget: $359,857
ODOT Support: Jon Rooper, P.E. Senior Load Rating Engineer, Jonathan.W.ROOPER@odot.oregon.gov, 503-302-6188; Ray Bottenburg, State Bridge Engineer, raymond.d.bottenberg@odot.oregon.gov, 503-551-7934

FOR MORE INFORMATION

For additional detail, please see the complete STAGE 2 RESEARCH PROBLEM STATEMENT online at: https://www.oregon.gov/odot/Programs/ResearchDocuments/24-23.pdf

SPR RESEARCH PROGRAM
SECOND-STAGE PROBLEM STATEMENT
FY 2024

PROBLEM NUMBER AND TITLE
24-23 New Methods for Improving Load Rating of Existing Steel Bridges.

RESEARCH PROBLEM STATEMENT
There are hundreds of steel bridges in Oregon that are in good condition and have performed well over extended lives. However, newly implemented rating checks for lateral-torsional buckling are now resulting in low rating factors that could require load posting for hundreds of bridges. Most of these steel bridges are simply supported steel stringers with either timber or corrugated metal decks and the bridges are located throughout the state. These bridges rated adequately using prior load rating methods, but recent updating of the load ratings using LRFR now produces very low rating factors for positive moment at mid-span. The main difference between the old and new methods is that lateral torsional buckling (LTB) controls the moment capacity and this was not checked in the old rating. There are cases where the rating factor is zero meaning the bridge cannot carry any truck load. ODOT load rating engineers have tried to develop analytical tools based on limited prior research but many bridges still have low ratings and require load posting.

One of the main contributors to the poor rating for LTB is that these older bridges were not designed for lateral torsional buckling and have limited or no positive connection between the deck and girders to brace the compression flange. It is understood that LTB is indeed a failure mode that needs to be evaluated, especially with some of the concentrated loads of modern vehicles, but research is needed to quantify the available bracing in existing steel bridges and more fully understand how truck loading on the bridge deck of a multi-girder steel bridge influences the system performance for establishing LTB load rating factors. In addition, rapid and efficient retrofit methods need to be developed that could be deployed to enhance compression flange bracing thereby eliminating the rating deficiency.
Improved understanding and new methods of analysis for LTB in older multi-girder steel bridges would enable the load rating analysis to properly account for existing mechanisms that can effectively brace the compression flanges, allow clearer communication of the LTB deficiency and provide methods to remediate it for both ODOT and local agency bridge owners, and thereby reduce or prevent the needless and costly posting of bridges throughout Oregon.

RESEARCH OBJECTIVES
The objectives of this research are to answer two questions. First, is it legitimate for LRFR load ratings to control the moment capacity for simply supported steel bridges due to LTB, even though there is no history of inadequate service performance? If so, then a clear explanation to bridge owners and the public is needed as to why this is so and why these bridges have not experienced such failures in practice. Second, given that LTB is a potential limiting failure mode that must be checked in LRFR, is/are there mechanisms acting in these older bridges that provides sufficient bracing to resist LTB and that has allowed them to perform so well in service for decades? Is so, analysis and rating methods that account for these system performance mechanisms in the load rating process are needed.

WORK TASKS, COST ESTIMATE AND DURATION
To achieve the research objectives, field studies, full-scale laboratory tests, analyses, and development of new rating methods are required. These actions will identify modes and mechanisms of failure, assess vulnerabilities of existing bridge designs, produce effective rating methods, and develop economical retrofit strategies. The experimental results will be compared with finite element and available code models for

prediction of capacity. The research program proposed to accomplish the objectives is envisioned to last 24 months, and consists of the following eight (8) tasks (note, many tasks to be performed concurrently):

Task 1: TAC Meeting. The research team will meet with the TAC to review the research plans and identify prototype bridges from which to select for field instrumentation and develop specimen details that accurately reflect the range of in-situ parameters.

Task 2: Literature Review. Prior research on lateral torsional buckling of steel and composite steel girders will be reviewed. AISC, AASHTO, and international code design approaches will be reviewed and compared. The review will summarize the state of knowledge, identify gaps, and ensure that new work advances the field to produce the required outcomes for ODOT practice.

Task 3: Develop Database of Bridges with LTB Controlling Ratings. A database of ODOT's steel bridges that rate insufficient due to LTB will be developed. The key characteristics will be captured and described. Attributes such as span length, girder spacing, girder size, deck type and connectivity, etc. will be quantified. This will be used to design relevant and realistic test specimens and to select bridges for field studies.

Task 4: Laboratory Experimental Design and Implementation. Using the results of Tasks 2 and 3, steel girder specimens will be developed that are representative of ODOT's existing inventory. Three (3) different girder sizes will be selected for use in the experimental program. Elastic LTB tests will be conducted in the laboratory using bare steel girder specimens (no deck connection) considering different span lengths, end restraint, beam sizes, and idealized bracing locations and stiffness. A second set of tests will consider system performance from multiple parallel steel girders with different deck types (concrete and timber) and friction connectivity between the deck and girders. Special loading conditions must be represented in all tests that permit out-of-plane bending and twisting of the girders while maintaining the vertical applied load. Realistic loading conditions typical of in-situ girders will be produced in the laboratory based on elastic analysis of bridge models with the controlling rating truck model locations. For the three (3) girder types, retrofit methods will be developed and tested to improve member strength and suppress LTB failure modes. The experimental results will be used in subsequent analysis tasks and field studies. Special consideration will be made to instrument specimens in a way that captures surface strains and relative deformations that can be used as telltale signs of impending LTB.

Task 5: Field Instrumentation and Testing. Using the results of Tasks 1, 2, 3 and 4, two (2) ODOT bridges that have very low ratings for LTB will be instrumented and tested in situ. Instrumentation will be deployed based on the laboratory test findings to capture LTB behaviors. Controlled load tests using ODOT maintenance trucks will be conducted to assess the response of the bridges and degree of composite action available. Field results will be compared to rating assumptions and laboratory observations. Analytical models of the bridges will be developed and compared to field measured results. Results of this task will be used to define key analysis parameters and refine rating methods.

Task 6: Comparison of Experimental Results with Rating and Analysis Models. The laboratory and field tests (Tasks 4 and 5) will be compared with existing codified design and rating approaches. Finite element models will be developed and validated based on the experimental observations. Model validation with test data will allow further analytical investigation of other parameters beyond those tested. The modelling requirements needed to capture behavior and strength will be defined and these will allow others to conduct advanced analyses where necessary to improve rating beyond more simplified and conservative approaches. Calibration of resistance factors for LTB of existing steel bridges, within the AASHTO LRFR framework, will be performed based on the statistical outcomes from the experimental results and prior research by others.

Task 7: Develop Rating and Retrofit Guidance. Following completion of the experimental and analytical tasks, appropriate rating guidelines will be developed to enable rating engineers to more effectively rate steel girders controlled by LTB that are presently identified as deficient. Specific specification language will be written to facilitate inclusion into existing rating codes and practices. In addition, guidance on design and construction practices will be provided for cases where retrofits are required based on the laboratory experiences and known best practices.

Task 8: Reporting with TAC meeting. A final report will be produced that documents the research methodology, findings, and recommendations. Detailed examples will be provided in an appendix for proposed rating and analysis methods. A TAC meeting will be held to discuss the findings and to assist ODOT in the incorporating the recommendations into ODOT rating practice. Presentations on the research will be made as appropriate to professional conferences and at AASHTO technical committee meetings (specifically T-14) with the intent to update the current AASHTO-LRFR bridge rating standards (MBE).

Key Deliverables: A report documenting a careful analysis of the structural system of steel bridges with simply supported steel stringers that reconciles past performance with current load rating methods, particularly with regards to LTB. Depending on the results of this analysis, a clear explanation for bridge owners and the public as to why these structures need reduced load ratings or a methodology for performing the load ratings that accounts for the mechanism(s) that constrains LTB.

Estimated Project Length: 24 months
Estimated Project Budget: $359,857

IMPLEMENTATION

The research to be conducted will develop experimental data, analytical models, load rating methods, and new retrofit design and construction recommendations based on field and laboratory experimental and analytical results. Research findings will be synthesized into a report with an appendix that demonstrates specification language that can incorporated into existing ODOT practices (ODOT Load Rating Manual) and AASHTO-LRFR specifications as has been demonstrated through past research products from the proposer.

POTENTIAL BENEFITS

Safety of the transportation system is of significant importance for all Oregonians and central to ODOT's mission to provide a safe and reliable multimodal transportation system. Bridge ratings that accurately reflect controlling limits such as moment capacity in steel bridges that could be affected by lateral torsional buckling are essential. Newly applied rating methods are now showing low load ratings hundreds of Oregon bridges that are in good condition. It is hoped that this research will limit the number of bridges that need to be posted. Additionally, the results should allow for modifications to be designed to restore normal load ratings. Bridge posting is contrary to ODOT's mission to connect people and helps Oregon's communities and economy thrive.

PEOPLE

ODOT champion(s):

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STAFF REVIEW PAGE

Literature Check

TRID&RIP

☒ A review of TRID & RIP databases found no existing research that answers the research question

Other state DOTs are encountering similar LRFR load rating challenges and there is some recently published material regarding LTB. However, there doesn't appear to be a definitive solution and the detailing of bridges in Oregon will likely diverge from the preliminary work that has been completed elsewhere.

Technology & Data assessment

☒ No Identified T&D output

☐ At the end of this project, the implementing unit(s) within ODOT will need to coordinate the adoption of new technology or data in order to realize the full potential of this research.

Cross-agency stakeholders

- List stakeholders or impacted units

The primary products proposed for this research effect only the Bridge Operations Unit of ODOT. However, the suggested design modifications component of this research will ultimately be implemented by the Bridge Design Unit. Both of these units are supervised by Ray Bottenberg.

- Identify any issues of concern raised by an ODOT stakeholder. Note expected mitigation