Texas Department of Transportation

CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY REPORT

0-7012: Development of Non-Fracture Critical Steel Box Straddle Caps

Background

Steel box straddle caps are an efficient solution for bridges located in congested urban environments when the use of a conventional pier is not possible due to the presence of intersecting roads beneath the bridge. Steel box straddle caps offers fabrication and erection advantages and high structural performance due to the large torsional stiffness of the box section. However, steel box straddle caps are classified as Fracture Critical Members (recently renamed as Nonredundant Steel Tension Members), requiring stringent design, fabrication, and in-service hands-on inspections to comply with the provisions of the Fracture Control Plan.

Providing internal redundancy to steel box straddle caps to remove the Fracture Critical inspection requirements is highly desirable for a number of reasons, including: improved safety due to a reduced probability of failure, reductions in traffic disruptions necessary for hands-on inspections, and significant savings both economy and maintenance demands for bridge owners. A detailed overview of all aspects of the study are provided in the Project 0-7012 final research report.

What the Researchers Did

Two design approaches to provide internal redundancy to steel box straddle caps were explored:

- Design Concept A: adding high-strength bars to arrest crack propagation and serve as secondary tension elements in the fractured condition; primarily intended for retrofitting existing straddle caps.
- Design Concept B: bolting the tension components (i.e., between the bottom flange and webs) to provide cross-boundary fracture resistance; mainly considered for new construction; however permutations might apply for retrofitting existing caps.

The research study included full-scale experimental testing and parametric finite element (FE) analyses, which resulted in a proposed methodology to estimate the flexural resistance of steel box caps following a potential fracture event. The work was conducted at the Ferguson Structural Engineering Laboratory at The University of Texas at Austin. The following major tasks were completed on this project:

1. Four full-scale specimens were tested to fracture by introducing an initial defect and cooling the steel to lower-shelf temperatures to induce brittle behavior:

i. Baseline Specimen: a conventional all-welded box girder with no internal redundancy

ii. Specimen A: an all-welded section with added post-tensioning bars anchored at

Research Performed by:
Center for Transportation Research

Research Supervisor:
Dr. Todd Helwig, CTR

Researchers:
Esteban Zecchin
Emma Williams
Chen Liang
Michael Engelhardt
Eric Williamson
Matthew Hebdon

Project Completed:
05-31-2023

the internal diaphragms as a secondary tension component

iii. Specimens B1 and B2: specimens with the bottom flange plate bolted to the rest of the section through flange connection plates, providing cross-boundary separation between these components

The internally redundant specimens (A, B1, and B2) were also tested to evaluate the flexural resistance in the fractured condition.

2. The results of the experimental tests were used to validate the FE modeling approach. The FE studies focused on the performance of the selected design approaches for internal redundancy in the fractured state under various loading conditions and for a range of geometries representative of those commonly found in practice. Cases with fractures occurring in either the bottom flange or one of the webs were considered. The influence of a fractured section on the effective torsional stiffness of the box cap was investigated.

3. The flexural strength of the box members with a fractured section obtained from the parametric analysis was compared to that estimated using the current design provisions for noncomposite box sectional members of the AASHTO LRFD Bridge Design Specifications (2020).

What They Found

The addition of the post-tensioning bars (Design Concept A) produced a performance improvement with respect to the nonredundant specimen but did not arrest the cracks as they propagated through the webs, considerably reducing the shear resistance of the box member. Hence, this design approach was not recommended for implementation at this time.

The cross-boundary separation provided by the bolted connection between the bottom flange plate and the rest of the cross-section (corresponding to Design Concept B) was found to effectively limit the crack propagation to only one tension component. Hence, the assumed fractured section can be sized to provide adequate resistance in the faulted state. Additionally, the influence of a fractured section in the global torsional stiffness of the member was found to be minimal, and, as a result, the current design methodology provided by the AASHTO LRFD Specifications can be used with minor modifications to estimate the capacity of these straddle caps in the faulted condition.

What This Means

Non-Fracture Critical steel box straddle caps can be achieved by bolting the bottom flange plate to the rest of the section. This approach implies minor changes to the current fabrication practices used for all-welded straddle caps. Additionally, internal redundancy could be provided to existing steel box straddle caps by bolting a secondary tension flange to the existing member.

For More Information

Project Manager:
Martin Dassi, RTI Martin.Dassi@txdot.gov

Research Supervisor:
Todd Helwig, CTR thelwig@mail.utexas.edu

Project Monitoring Committee Members:
Tom Fan, David Fish, Jamie Farris, Paul Rollins, Wanching Huang, Yongqian Lin

Research and Technology Implementation Division
Texas Department of Transportation
125 E. 11th Street
Austin, TX 78701-2483

www.txdot.gov
Keyword: Research

Technical reports when published are available at
https://library.ctr.utexas.edu.