2022-29TS
Published November 2022

DEPARTMENT OF TRANSPORTATION
OFFICE OF RESEARCH & INNOVATION

TECHNICAL SUMMARY

Questions?
Contact research.dot@state.mn.us.

Technical Liaison:
Yihong Gao, MnDOT
Yihong.Gao@state.mn.us

Investigator:
Ben Dymond
University of Minnesota Duluth

PROJECT COST:
$181,243

Strain gauges measure the load distribution across the width of the bridge.

Updating Load Ratings for Shingle Creek Slab-Span Bridges

What Was the Need?

Efficient freight hauling routes around Minnesota are needed to control fuel and labor costs, meet consumer demand and ultimately maintain a healthy economy. A critical trucking corridor in the metro area along I-94/I-694 crosses over Shingle Creek on three slab-span bridges. Demand on these bridges has grown as customer expectations have risen and the volume of transported freight has dramatically increased.

When trucks exceeding the legal weight limits seek to cross the bridge, MnDOT issues overweight permits after analyzing the bridge type and configuration, live loading and other factors to ensure safe passage. Some larger trucks not eligible for overweight permits are forced to detour an extra 15 miles on more congested roadways.

Detours around bridges in a critical freight transportation route create costs to the trucking industry, taxpayers and state economy. New load rating factors for the slab-span bridges across Shingle Creek will give MnDOT more flexibility in managing truck traffic and keeping freight moving efficiently.

Current load restrictions are generally calculated with American Association of State Highway and Transportation Officials (AASHTO) bridge rating software. Live load testing around the United States, however, has found load ratings for many slab-span bridges to be overly conservative. Load ratings can be revised when significant improvements, replacement or other changes to a bridge occur. The Shingle Creek bridges, two of which were constructed in the 1960s and one in the 1980s, are not scheduled for significant improvements or replacement, thus there were no expected load rating reviews.

To ensure the safest and most efficient haul routes, MnDOT sought a robust assessment of the load capacities of these bridges to determine if load ratings and the overweight permitting process could be updated.

What Was Our Goal?

The goal of this project was to investigate three concrete slab-span bridges over Shingle Creek near Brooklyn Center, Minnesota, and conduct a detailed analysis of load distribution to assess whether current calculated load ratings reflect actual bridge behavior.

What Did We Do?

Investigators combined field testing with two modeling techniques to explore an alternative method of evaluating bridge load distribution behavior. After creating a preliminary model to identify specific bridge characteristics, researchers examined and tested two of the three side-by-side bridges. Fortuitously, nearby construction closed the bridges to traffic for two consecutive weekends, allowing for more uninterrupted investigation.

Researchers visually inspected the bridges for cracking, which may alter the bridge response under loading. To analyze strength and elasticity of the materials, they examined concrete core and steel reinforcement samples previously extracted by a MnDOT crew. Then they performed both static and dynamic loading tests on the bridges. Between the two bridges, three-axle trucks were placed in 89 different locations and configurations to illustrate static loading behavior. A truck crossing at the posted speed limit four times, dynamic impact hammer testing in 25 locations and 20 impact hammer strikes allowed researchers to observe bridge responses under dynamic

continued

"This research gives MnDOT an alternative—and more accurate—method to evaluate load ratings of slab-span bridges. We can now implement a more flexible permitting process for trucks, alleviating costly bottlenecks and detours."

—Yihong Gao,
Bridge Rating Engineer,
MnDOT Bridge Office

"We found that the load rating factors produced by our bridge-specific model and validated with field data were up to 24% greater than the ratings derived through the AASHTO process, which will benefit Minnesota's trucking industry, taxpayers and the economy."

—Ben Dymond,
Associate Professor,
University of Minnesota Duluth Swenson College of Science and Engineering

Produced by CTC & Associates for:
Minnesota Department of Transportation
Office of Research & Innovation
MS 330, First Floor
395 John Ireland Blvd.
St. Paul, MN 55155-1899
651-366-3780
www.mndot.gov/research

Load testing while the bridge was closed due to other construction allowed researchers to assess many different truck configurations and load distributions across the bridge's width.

loading scenarios. Strain gauges, displacement transducers and other equipment set up under the slabs measured movement and changes in the bridges during the load tests.

A complex, 3D finite element model was created based on design plans and confirmed by visual inspection of the layout and condition, including cracks of certain sizes. A simpler plate model was also created to estimate bridge loading responses, and researchers validated both models with the field data. They compared live load distribution factors generated from the field data, each model and AASHTO's bridge design software.

What Did We Learn?

Researchers developed live load distribution factors with computational models and field data to determine bridge demand and safe permit load ratings. Comparing modeling and field data results to the AASHTO load distribution factors, they found the AASHTO ratings to be conservative. They also found that the strength and elasticity of the concrete and steel samples tested were significantly higher than design values for those materials. Using measured rather than design values had marginal implications, however, for the load distribution as estimated by the models. Researchers recommended that MnDOT use the plate modeling technique and design material values for load rating the slab-span bridges over Shingle Creek.

Additionally, investigators outlined the process to calculate load ratings for slab-span bridges based on the plate model. Using one of the evaluated bridges as an example, they described the process for using the bridge design plans, locating boundary conditions for the model and selecting the vehicle properties and their locations to test. Unless material samples and elasticity measures are available for the structure being evaluated, design material properties should be used. Strain and displacement should be evaluated at points across the bridge's width to calculate the live load distribution factor.

What's Next?

MnDOT can use the new load rating process to evaluate other slab-span bridges in its inventory. The agency can also apply the methods to different types of bridges and other structures such as concrete box culverts.

This Technical Summary pertains to Report 2022-29, "Load Rating Assessment of Three Slab-Span Bridges Over Shingle Creek," published August 2022. More information is available at mndot.gov/research.