2016-32TS
Published November 2016

RESEARCH SERVICES & LIBRARY

OFFICE OF TRANSPORTATION SYSTEM MANAGEMENT

TECHNICAL SUMMARY

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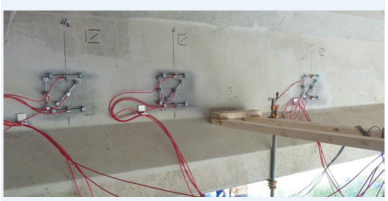
PROJECT COST:
$363,000



Researchers used strain gauges to determine shear distribution in prestressed concrete girders.

# Ensuring Accurate Load Ratings for Shear in Bridges with Prestressed Concrete Girders

*By improving the accuracy of estimates of live load shear distribution, this project will help engineers ensure the safety of Minnesota bridges, make cost-effective maintenance decisions and process overload permits for heavy trucks.*

## What Was the Need?

To ensure the safety of Minnesota bridges, MnDOT regularly gives them a load rating, a number that reflects the capacity of various components of the bridge, including individual girders, to carry vehicles of certain weights. These ratings are also important for processing overload permits, which allow vehicles with weights exceeding legal limits to travel within Minnesota along preapproved routes. Load ratings are calculated for new bridges, rehabilitated bridges and bridges shown by inspection to have deteriorated or been damaged.

To establish load ratings, engineers perform calculations using data from the bridge's original design plans and its latest field inspection reports. One of those calculations is to determine the distribution of live load—the load of traffic after excluding the weight of the structure—across the girders. Engineers express that distribution through numbers called distribution factors. These factors take into account the forces that run vertically through the girder, called shear forces, as well as bending forces.

In calculating load ratings and evaluating shear, engineers generally rely on the specifications produced by the American Association of State Highway and Transportation Officials (AASHTO). However, AASHTO requirements have changed over the years. As a result, Minnesota and other states have found that some concrete bridges designed according to previous AASHTO standards rate poorly for withstanding shear by current standards, even though the bridges show no signs of distress under normal traffic loading conditions.

## What Was Our Goal?

The purpose of the project was to investigate live load shear distribution and the accuracy of MnDOT's existing shear distribution factors for the load rating of bridges with girders made of prestressed concrete.

## What Did We Do?

Researchers used a multipronged approach consisting of numerical modeling and tests in both the laboratory and the field. The numerical modeling was used to apply the results of the lab and field tests to a study examining the effects of key parameters on the distribution of shear in a bridge system. Parameters included span length, girder spacing and depth, deck thickness and load position.

Researchers constructed a full-scale single-span concrete bridge in the laboratory to calibrate and validate the numerical model's representation of the bridge. In addition to the girders and a deck, the laboratory bridge included a traffic barrier running along the length of one of its edges, and a diaphragm connecting the girders at one end of the span. The barrier and diaphragm were believed to potentially affect live load distribution. Researchers loaded the laboratory bridge at different locations. They used strain

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A full-scale single-span bridge with four prestressed concrete girders was constructed in the laboratory and tested to investigate shear distribution.

gauges to monitor the effects of loading on shear and the distribution of shear among the girders along the bridge span.

In practice, when investigating the shear capacity of bridges, researchers amplify expected loads to the point of imminent bridge failure to measure the demand on the girders at ultimate strength. Researchers conducted two tests to failure on two diagonally opposite quadrants of the bridge, in order to determine whether shear distribution would change. They removed the barrier from the bridge before testing, in order to investigate results with and without a diaphragm.

The researchers also conducted a field study of six MnDOT bridges that had been rated low for capacity to withstand shear. They loaded the bridges with trucks full of sand at different points along the length and width of the bridge decks, and they used strain gauges attached to the surfaces of girders to measure the effects of those loads on shear distribution.

Additionally, researchers conducted tests on a single girder in the field that was identical to the girders used in the laboratory bridge. This provided an opportunity to investigate the capacity of a single girder relative to the multiple girders within the bridge system. Two girders removed from existing bridges were also load-tested to failure to compare the girders' actual shear capacity with their nominal strength.

## What Did We Learn?

Results showed that shear forces for some bridges are not as high as predicted by current AASHTO distribution factors, at least partially explaining why some MnDOT bridges with low shear ratings show no signs of distress. The researchers also found that the barriers did not significantly affect girder shear distribution and that both diaphragms and barriers could be ignored for the sake of calculating live load distribution. They provided recommendations for more refined methods of evaluating prestressed concrete girder bridges that rate low for shear, and developed a screening tool to identify which bridges that rate low for shear should be further analyzed to more accurately determine their anticipated shear demand.

## What's Next?

MnDOT will use the methods developed in this project to re-evaluate girder shear capacity for all concrete bridges in its inventory that have low shear ratings. MnDOT also is reviewing results for inclusion in its load rating manual.

*"The results of this project will help us re-evaluate aging bridges in our inventory, to distinguish those that really do have shear problems from those that don't, and make decisions about whether they need to be replaced or rehabilitated for extra capacity."*

**—Yihong Gao,**
Bridge Designer,
MnDOT Office of Bridges and Structures

*"One of the benefits of this project is making sure that overload vehicles are not being needlessly restricted from passing over bridges because of excessively conservative shear distribution estimates."*

**—Catherine French,**
College of Science and Engineering Distinguished Professor,
University of Minnesota Department of Civil, Environmental, and Geo- Engineering


*This Technical Summary pertains to Report 2016-32, "Investigation of Shear Distribution Factors in Prestressed Concrete Girder Bridges," published September 2016. The full report can be accessed at* mndot.gov/research/TS/2016/201632.pdf.

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