



## RESEARCH SERVICES & LIBRARY

OFFICE OF TRANSPORTATION  
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## TECHNICAL SUMMARY

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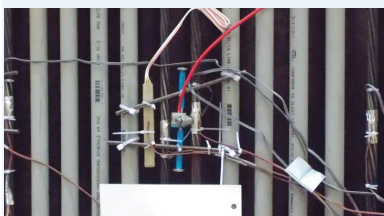
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### Principal Investigators:

Catherine French and Tanner Swenson,  
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### PROJECT COST:

\$132,345



To study prestressing strand temperature and force, researchers instrumented strands with thermocouples and strain gauges.

# Reducing Loss of Concrete Bridge Girder Prestress Force by Accounting for the Effects of Temperature

## What Was the Need?

In order to provide the necessary strength, MnDOT typically reinforces concrete bridge girders with steel prestressing strands. Fabricating prestressed girders involves pouring concrete around these strands after they have been tensioned along a casting bed and releasing them once the concrete has hardened. Because these strands are located primarily near the lower portion of the girder, when released they precompress the bottom to create an upward bend in the beam, called camber. The pre-compression provides strength in the girder to resist the downward loads it carries.

As the concrete around prestressing strands cures, the reaction of the concrete mixture with water (called hydration) increases its temperature. This causes the steel strands to heat up, reducing their tension and the amount of force they will apply to the surrounding concrete. The result is a reduction in the load that it takes to cause cracking in the beam and reduced beam camber. It is important for beams to have the right prestressing force and camber, so they will be durable and fit properly with other bridge components during construction.

If the loss of force caused by the temperature rise in the strands can be predicted, this loss can be offset during fabrication by increasing the initial tension of prestressing strands, which in turn will improve estimates of camber. This requires knowing how much force steel strands will lose before they bond to the surrounding concrete. Bonding locks the concrete and steel together, preventing further loss of unrecoverable force in the strands. Consequently, research was needed to establish how long bonding takes to occur and also the temperature of the concrete and strands at the time bonding occurs.

## What Was Our Goal?

The objectives of this study were to:

- Investigate the effects of temperature on strand force and camber during the fabrication of precast, prestressed girders, including the time and temperature of strand-to-concrete bonding.
- Make design and fabrication recommendations that will reduce the loss of prestress forces due to temperature changes.
- Recommend an improved method for estimating the release cambers of beams.

## What Did We Do?

Researchers established a method for thermal effects analysis to estimate strand force changes throughout the girder fabrication process, which enabled them to predict beam camber both immediately after release and after cooling. They compared the results of this methodology to experimental observations obtained through a series of field tests.

*By better understanding and reducing the loss of force in girder prestressing strands, engineers can help ensure the durability of bridges and better predict camber, the upward bend in the girder caused by the prestress force.*

*“This project is unique in providing data used to establish the temperature at which prestressing strands can be assumed to bond to concrete during fabrication. This information is key in determining the nonrecoverable loss in prestress force due to temperature changes during fabrication.”*

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

*“We’d like to have as close a prediction as possible of the prestress force to ensure that designers are getting the prestress they have assumed for their designs, and that the cambers during construction allow proper placement of the bridge deck.”*

—Dave Dahlberg,  
Bridge Design Manual and Policy Engineer,  
MnDOT Bridge Office

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To determine the time and temperature of strand-to-concrete bonding, researchers cast short girder sections around instrumented prestressing strands.

To investigate bonding between strands and concrete, researchers cast six short prestressed concrete girder sections and released strands at different times early in the curing process, while measuring changes in strand and concrete forces. By applying thermal effects analysis to these results, they determined the time and temperature of strand-to-concrete bonding for the typical MnDOT prestressed concrete girder mix.

To investigate loss of strand force due to temperature and the effects on camber, the researchers monitored four sets of full-scale girders during fabrication, from the time of tensioning to release. These included two types of girder shapes, MN54 and 82MW, cast during warm or cold seasons, and cast with different casting bed conditions. They measured strand force and temperature as well as concrete strength and stiffness. Finally, researchers applied thermal effects analysis to temperature readings to estimate strand forces and compared these estimates to direct measurements of strand force changes.

### What Did We Learn?

Results for short girder sections showed that for the typical concrete mix used in MnDOT bridge girders, bonding would generally occur when concrete reaches a temperature of 100 degrees Fahrenheit, between six and eight hours after casting in mild summer weather. The full-scale girder results were consistent with the estimated time of bonding for the short girder sections.

Based on the four sets of full-scale girders monitored, researchers estimated that there was potential to lose up to 4.5 percent of the strand force between tensioning and bonding due to the temperature changes in the girders studied. However, the plant reduced these losses to a maximum of 2.6 percent through their current fabrication process. As an example, the plant covers the strands with a tarp and heats them prior to tensioning in cold weather, lowering potential temperature differences in the time between tensioning and bonding.

Researchers found that MnDOT’s current methods overestimate release cambers by 44 percent for MN54 girders and 95 percent for 82MW girders. Previous research showed that by increasing the design concrete strength by 15 percent and using a different model for estimating concrete modulus of elasticity, overestimation is reduced to no more than 15 percent for MN54 girders and 47 percent for 82MW girders.

### What’s Next?

MnDOT is reviewing new methods proposed by researchers for predicting camber and adjusting strand tension to offset the loss of force due to temperature changes in the curing concrete and strands. Researchers recommend further study of the effects of thermal gradients on camber, and how the number and distribution of girders being cast simultaneously in a single bed affect their temperature. Reducing girder prestress losses and more accurately estimating camber will help MnDOT to improve the safety, durability and longevity of its bridges.

*This Technical Summary pertains to Report 2015-50, “Effect of Temperature on Prestressed Concrete Bridge Girder Strand Stress During Fabrication,” published December 2015. The full report can be accessed at [mndot.gov/research/TS/2015/201550.pdf](http://mndot.gov/research/TS/2015/201550.pdf).*