Improving Camber Estimates in Minnesota Bridge Girders

What Was the Need?
Since the 1950s, employing prestressed concrete girders has offered Minnesota bridge engineers an economical, low-maintenance design option for increasing girder strength, durability and stiffness. Prestressing involves casting the concrete around stretched steel strands. When the concrete hardens, the strands are released. The strands then contract, compressing the concrete. Because these strands are located primarily in the bottom of the girder, there is more compression there than at the top. This counteracts the tension created by traffic loads and the weight of the girder itself, helping to prevent cracking. The upward deflection caused by the prestress is called camber.

Because of such factors as concrete shrinkage and temperature, the camber of a girder immediately after the release of prestressing strands, or release camber, can differ significantly from the camber it will have during construction, or erection camber. Engineers must take into account erection camber when designing bridges; if its design value is inaccurate, there can be construction problems in fitting the bridge deck to the girders and roadway profile, leading to delays and increased costs.

Engineers use a multiplier to calculate erection camber from the predicted release camber. Inherent uncertainty in some of the factors affecting these cambers can introduce errors in estimating the actual cambers from the predictions. It was recently observed that girders being erected at bridge sites in Minnesota often had much lower than predicted erection cambers despite MnDOT’s modification of its multiplier method in 2007.

What Was Our Goal?
The objective of this study was to improve MnDOT’s bridge girder camber prediction methods by investigating factors affecting both release and erection cambers, quantifying the relative uncertainty in the different factors and creating a new set of multipliers taking into account these factors.

What Did We Do?
Researchers began by analyzing:

- **Current release camber prediction accuracy** by examining camber records for more than 1,000 girders from two precasting plants and from measurements taken during the erection of Minnesota I-girders produced between 2006 and 2010 to compare measured camber values to design values.

- **Factors affecting release camber** by testing concrete samples at these precasting plants to determine the concrete compressive strength and elastic modulus over time, and comparing these values to the assumptions used in design.

- **Thermal effects** of concrete and ambient temperatures on the strand stress at release.
Researchers used these analyses to devise an improved method for predicting release cambers and tested it on a data set for which detailed fabrication information was known, including curing and temperature records.

Researchers then investigated factors affecting long-term and erection cambers, including solar radiation, relative humidity, concrete creep and shrinkage, length of cure and storage conditions. They used the resultant computer modeling to perform long-term predictions of camber for girders of varying depths and lengths. By comparing these predictions to current MnDOT and improved release camber predictions, researchers created four sets of multipliers, allowing the calculation of more accurate release and erection camber predictions. Researchers applied these multipliers to the historical girder data set and compared results to the measured erection camber data.

**What Did We Learn?**

From historical data, researchers found that measured camber values differed significantly from those for which they were designed. On average, the release camber of girders was only 74 percent of the design value, and the erection camber only 83 percent. Concrete compressive strength attained at the precasting plants was often greater than the design value, leading to greater stiffness and decreased camber. Current methods used in design underestimated the concrete modulus of elasticity from the concrete compressive strength. Also, strand stress at release was lower than predicted because of thermal effects and strand relaxation.

With better estimates for these factors, researchers created a more accurate method for predicting release cambers, improving the average discrepancy between measured and design release camber values from 74 percent to 99 percent. They also created sets of multipliers that, on average, improved the accuracy of erection camber predictions to between 95 percent and 97 percent of the design value. There is still scatter in the results due to inherent uncertainties involved in the construction process. The multiplier sets for erection camber include an option for using a single multiplier or various multipliers, depending on the age ranges of the girders at erection, to reduce the scatter in the results.

**What’s Next?**

MnDOT is currently evaluating the multiplier options and other recommendations developed.