Instrumentation, Monitoring and Modeling of the I-35W St. Anthony Falls Bridge

What Was the Need?
Completed in September 2008, the new I-35W St. Anthony Falls Bridge consists of two parallel structures for northbound and southbound traffic. Each structure consists of post-tensioned concrete box girders, or hollow bridge beams. Post-tensioning involves running steel strands through ducts within the beams and tightening them with a hydraulic jack, which compresses the beam and makes it less susceptible to cracking.

The bridge was also constructed to include a “smart bridge” system consisting of hundreds of sensors to monitor how the structure bends and deforms in response to traffic loads, temperature changes and the effects of material deformations due to creep and shrinkage. For several years, the University of Minnesota has been monitoring and analyzing these data to help improve future bridge designs.

What Was Our Goal?
The purpose of this project was to investigate the performance of this bridge, compare it with expected performance based on design assumptions in the bridge’s load rating manual, and better understand the structural behavior of post-tensioned concrete box girder structures in the Minnesota environment.

What Did We Do?
During construction, the I-35W Bridge was instrumented with more than 500 sensors to collect data related to structural behavior in response to traffic loads, temperature changes, creep and shrinkage, including:

- Structural deformations via vibrating wire strain gages, resistive strain gages and fiber optic strain gages.
- Temperature via thermistors.
- Structural vibrations via accelerometers.
- Overall expansion and contraction of the bridge via linear potentiometers located at the expansion joints.
- Electrochemical activity and concrete resistivity as indications of the potential for corrosion via sensors located in the deck.

To further explore structural responses, researchers also developed three-dimensional and two-dimensional computer models of the bridge. The parameters used in these models were determined by laboratory tests of concrete samples taken during construction to measure such properties as strength and stiffness.

To validate these models and establish a baseline for interpreting bridge data, researchers measured the deformation of the bridge in response to eight loaded trucks stationed in various configurations and locations. They also evaluated the bridge’s response to these trucks being driven across it in several configurations, both while the bridge was closed and with regular traffic.

By closely monitoring how the new I-35W St. Anthony Falls Bridge responds to traffic loading and temperature variations, MnDOT can refine its designs for similar bridges, making them more durable and economical for the traveling public.
Finally, all of these data were used to evaluate the accuracy of the assumptions in the load rating manual for the I-35W Bridge.

**What Did We Learn?**

The bridge behaved as expected, and computer models accurately predicted its measured responses. Its most notable response was to daily and seasonal changes in temperature, which had a greater effect on mechanical strain than truck tests.

Computer models accurately predicted the structural changes of the bridge in its longitudinal direction. They reasonably predicted torsion, or twisting about the bridge’s longitudinal axis, and local deformation, or deflection in specific regions of the bridge. Researchers also validated the ability of the models to predict the response due to thermal effects, including thermal gradients, or distributions of temperatures through the bridge cross section.

The measured temperature gradients differed substantially from those predicted by AASHTO design recommendations, and the deformations and stresses calculated using AASHTO’s LRFD bridge manual were only 60 percent of the maximums measured for the bridge. Nevertheless, researchers found the methodology detailed in the I-35W Bridge’s Inspection and Maintenance Manual to be sufficient for estimating the overall elongation of the structure due to uniform temperature changes.

Researchers also documented several areas in which the original load rating manual predictions of bridge behavior were inaccurate or too conservative, and others that produced reasonable approximations. Finally, they provided recommendations about the efficacy of the bridge’s sensors to improve procedures for monitoring future bridges.

**What’s Next?**

Researchers will continue to monitor sensor data from the I-35W Bridge to investigate the time-dependent response of the bridge due to long-term effects of creep and shrinkage. In the follow-up project, “Time-Dependent Considerations of I-35W St. Anthony Falls Bridge Including Long-Term Monitoring Applications,” researchers will compare the predictions of several creep and shrinkage models to the measured response of the bridge obtained over the first four years. The models will be used to predict the expected long-term deformations over the life of the structure.

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During construction of the I-35W Bridge, Roctest EM-5 strain gages were cast within the bridge’s concrete to measure strains from traffic loading and temperature variations. Researchers also installed external strain gages within the box, which, unlike internal gages, can be replaced if they malfunction.

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