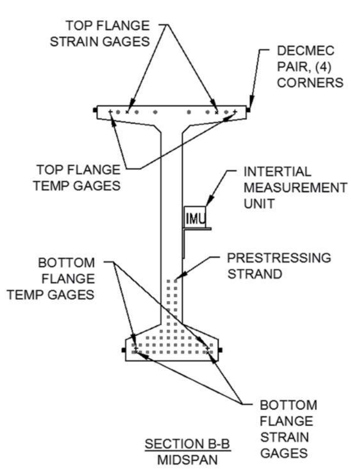
Active Monitoring of the Transport of Long-Span Precast Concrete Girders

by Richard E. Lindenberg and Jonathan C. McGormley, Wiss, Janney, Elstner Associates Inc.

The recently released PCI *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders* serves as a reminder of a particularly challenging problem for long-span bridge girder designers. What design forces should girders be required to resist prior to their installation and incorporation into the permanent structure? A particular issue lacking definition from available research is the behavior of girders during transportation. Very little real-world data have been gathered on this issue and yet there are reports of instances where girders were damaged during transport outside of lifting or accidents.

Research

In 2011, the Louisiana Department of Transportation and Development (LaDOTD) awarded Wiss, Janney, Elstner Associates Inc. (WJE) a research study to examine the transportation of precast concrete long-span girders to the jobsite. As a part of this research, WJE instrumented two 130-ft-long precast, prestressed concrete girders. One girder was an American Association of State Highway and Transportation Officials (AASHTO) Type IV and the other was a 72-in.-deep bulb tee (BT72). Monitoring occurred from moving the girders from storage to the truck through transport to the site and lifting from the truck. The girders traveled similar routes that exceeded seven hours in transit across Mississippi and Louisiana, and included a variety of roadway geometries commonly identified as possible contributing factors to girder damage during shipping (such as non-horizontal grades, railroad crossings, superelevation, bridge expansion joints, and the like). Supplementing the research were material testing and analytical modeling to better understand girder behavior.



Typical cross section showing instrumentation. See figure at right for instrumented cross-section locations along girder. All Photos and Figures: Wiss, Janney, Elstner Associates Inc.

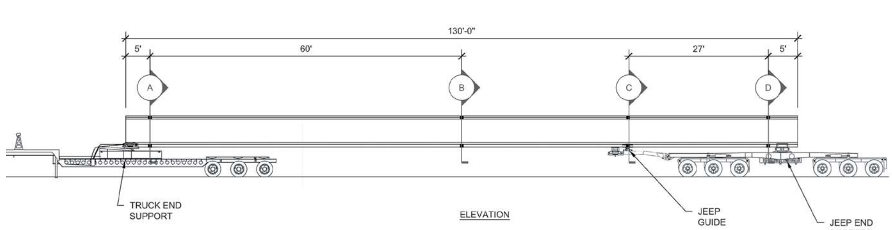
The girders were instrumented with a variety of dynamic strain, temperature, and inertial sensors (comprising three-dimensional rotation displacement sensors with rate of rotation, along with translational triaxial acceleration sensors) to measure the behavior of each girder during transport. Additionally, geolocation of the girders was recorded to correlate significant events of the transport to measured readings.

Both girders were supported in similar fashion, with a three-axle tractor pulling a fifth-wheel three-axle trailer supporting the front end of the girder that was positioned on a rotating bunk and a Hydra Steer six-axle rear jeep supporting the back end of the girder. The rear jeep provided considerable maneuverability, permitting the single driver/operator to efficiently steer the girder through a variety of maneuvers. The rear jeep was capable of operating in different steering configurations based on the navigation circumstances required. A single driver both drove and operated the rear jeep steering during transport of both girders.

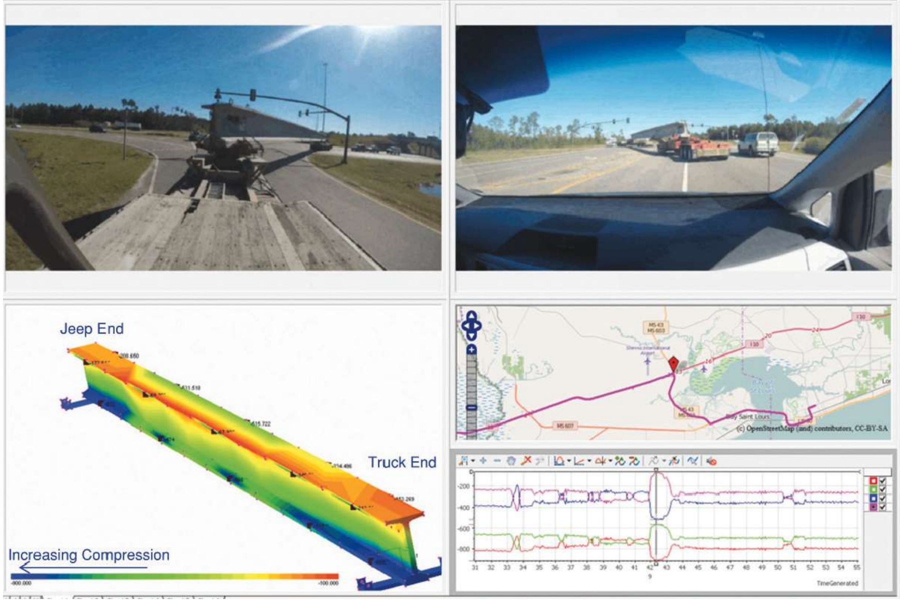
Data Collected

Both girders traveled from Pass Christian, Miss., through Louisiana on Interstate 10 into Baton Rouge, La. From there, the transports deviated with one girder traveling to Alexandria, La., and the other to Lake Charles, La. For each girder, over 40 channels of instrumentation were collected at 100 Hz to record individual events along the route. Time-lapse video correlated with geolocation data allowed the research team to review events along the shipping route. The data were fused to correlate time lapse, geolocation, traditional time versus strain response, and sensor-mapped imagery.

A significant challenge of this research was to efficiently investigate many hours of collected data. The fused data was not intended to accurately identify critical stresses and girder position, but



Location of instrumented cross sections along girder.



Data fusion of traditional strain plots, with synchronized time-lapse video, geolocation map, and interpolated three-dimensional sensor mapping.

rather was used to assist the investigators with the rapid interrogation of girder response while simultaneously observing time-lapse video correlated to events of interest, for example, turns and railroad tracks. The strain gage placement permitted peak responses to be captured during transport

Notable Findings

WJE reviewed the data for maximum responses along with notable correlation between inertial and strain measurements. The data confirmed expectations that the Type IV girder had lower horizontal flexural bending responses than the BT72 to similar turning events, which is consistent with the differences in geometric section properties between the two girders. Typical highway transportation, including changes in superelevation, transport across railroad tracks, and riding over bridge expansion joints produced relatively minor strain activity in both girders.

The most notable finding was that measured strains exceeded predicted cracking strains in both girders. Low-speed maneuvers, such as tight turns, produced the greatest tensile strains in both test girders during transport. Based on a review of these events, these strains were principally due to the lateral force introduced by the jeep tongue.

Accordingly, in many cases the girders experienced the highest tensile strains at the location of the jeep tongue, and not at midspan of the girder. Therefore, the force input by the jeep tongue strongly influenced the girder bending response. This force is a consequence of the driver's operation of the jeep, with no direct feedback to the driver on the magnitude of that force. This exceedance occurred several times for both girders during transport. The largest strain responses from standard transport activity occurred during low-speed maneuvers (less than 10 mph) that relied on the engaged jeep tongue to turn the rear bunk, such as the turn onto the interstate ramp. Post-transport inspection found no visually observable cracks in either girder.

Girder turning onto an interstate ramp, an example of a significant event causing differential bending strain at the top flange of the girder.

Conclusion

This research provides insight into girder behavior during transport based on actual measured response. In particular, it highlights circumstances where truck-girder interactions due to driver maneuvers produced girder responses that had not been previously identified in research. Both girders experienced events during otherwise routine transport that exceeded predicted cracking strains. The location and magnitude of these jeep-tongue-induced strains are not typically considered by designers or precast producers for girder transportation. To better understand how cracking during transport can be minimized, research to quantify imposed forces on girders by drivers' actions during transport is recommended, including additional field testing of various transport trailer systems and full-scale lab testing using actuated support conditions derived from actual field-generated time-history responses.

The research was significantly complete by the time the PCI *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders* was made available to the public. The investigators have since reviewed the this recommended practice and have found that many of the same references used in the PCI document were included in their work. Moreover, the PCI *Recommended Practice for Lateral Stability of Precast, Prestressed Concrete Bridge Girders* suggests a wide array of loading conditions; however, loading of the girder through the transport jeep tongue via driver operation was not incuded. Given the findings of the LaDOTD research, it appears that this should be considered.

The complete research report (Report No. FHWA/LA.16/567 *Development of Guidelines for Transportation of Long Prestressed Concrete Girders*) is available online from the Louisiana Transportation Research Center at https://www.ltrc.lsu.edu/pdf/2016/FR_567.pdf

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