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Development of Guidelines for Transportation of Long Prestressed Concrete Girders

INTRODUCTION

This research study investigates the behavior of two long, prestressed concrete girders during lifting and transportation from the precast yard to the bridge site, with a particular focus on cracking and stability concerns during transport. Different response measurements were recorded, including dynamic strains, dynamic accelerations, thermal, and rigid body motion measurements, while the girders were tracked using a global positioning system.

OBJECTIVE

The objective of this research was to develop guidelines that DOTD can apply to the future design and transportation of long-prestressed concrete bridge girders to avoid cracking. The guidelines would define acceptable methods of girder support during transportation, recommend safe girder response limits during transportation, suggest road conditions/geometries to be avoided on transportation routes, and advocate design changes to improve girder shipping performance.

SCOPE

This research examined the behavior of two long-span, prestressed concrete girders during transportation and lifting at the yard and bridge site. A key aspect of this study was to determine if cracking events occur before erecting the girders and to investigate the reason for those events. Thus, cross sections in each girder were instrumented with sensors to measure responses from initial girder casting to the transport of the girder to the bridge site. These responses included concrete strains, multi-directional accelerations, roll and deflection estimates, and temperature. From detailed analyses of these results, suggested recommendations to better quantify the loads causing cracking and to reduce the potential for cracking were developed.

METHODOLOGY

Two 130-ft. girders were instrumented with strain gages, inertial measurement units, and thermocouples to measure the girder response during transportation and lifting. Strain, roll, acceleration, and temperature measurements were recorded at the top and bottom flanges of cross-sections located at the ends and the middle of the girder, along an addition cross-section of strain measured near the critical jeep cross-section. Monitoring of the girders took place during lifts and for the entire transportation route across Louisiana over a full spectrum of roadway geometries and characteristics. Transport monitoring was supplemented by geographical positioning information and synchronized time-lapse video.

To further understand the behavior during transportation, as well as determining when cracking would likely occur, the long-term state of strain was evaluated using laboratory creep and concrete material property testing. These results were supplemented through periodic field measurements obtained from demountable mechanical gage points at multiple cross-sections. Using this information and a review of the full transportation event record, finite element method (FEM) modeling was used to analyze the observed behavior and evaluate the influences of girder shape, girder length, roll sensitivity, and jeep tongue forces.

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PRINCIPAL INVESTIGATOR:
Jonathan C. McGormley, P.E., S.E.,
Richard E. Lindenberg, P.E., S.E

LTRC CONTACT:
Walid Alywan, Ph.D., P.E.
225.767.9109

FUNDING:
SPR: TT-Fed/TT-Reg

Louisiana Transportation Research Center

4101 Gourrier Ave
Baton Rouge, LA 70808-4443

www.ltrc.lsu.edu

CONCLUSIONS

Prior research has recognized that girder transportation is fundamentally complex. Most of the research in the past has been focused on lifting of long girders, as this is traditionally seen as a more critical event in the life of the girder. However, based on analyses of the girders in this study and previous related research work, cracking strains were readily experienced during girder transport and were larger than the lifting strains. These findings have implications for how long prestressed concrete girders should be handled to avoid cracking. Some of the greatest tensile strains imposed on the girders were the result of controllable events (i.e., tight turning radii) and not due to less controllable phenomenon such as roadway super-elevation along the delivery route. Additional findings from this research include the following:

1. High strain events in the transportation records of both girders were associated with low-speed (<10 mph) maneuvers with high roll angle (>3 deg.) and the presence of a lateral force from the jeep tongue.
2. The most critically loaded girder cross section was at the jeep tongue attachment.
3. Typical roadway conditions encountered during transportation did not necessarily relate to increases in tensile strain levels.
4. The highest recorded strains during the transportation of both girders occurred when the jeep tongue was attached to the girder during sharp turns.
5. Drivers received no feedback regarding the amount of force applied by the jeep tongue during sharp turns.
6. Girder shapes with higher prestressing force and lateral stiffness would be expected to be more resistant to cracking during transportation.
7. Lifting the girders yielded lower tensile strains than the maximum recorded during transportation.
8. The change in girder behavior between lifts suggests the girders did crack and that cracked section properties should be utilized.

RECOMMENDATIONS

The results of this research study show that cracking and stability of long, precast concrete girders (>100 ft. in length) during transportation can be affected by both the designer and the precaster. The current research has shown that longer girders are at a greater risk for cracking and stability issues during transportation. However, this cracking risk can be mitigated to some extent considering the following recommendations presented:

1. Consider all girder lifting and transportation events from fabrication through erection, with specified procedures in place for each of these events (e.g., when to attach and remove the jeep tongue and prohibitions on moving the jeep when stationary.)
2. Installation of force limitors or pressure sensors that either prohibit or warn the jeep operator when lateral forces applied by the jeep tongue against the girder exceed established thresholds.
3. Designers should assume that cracking strains would likely be experienced for longer girders in the upper flange at some point during transportation. Consider tongue lateral force in evaluating transportation stresses.
4. Temporary post-tensioning of the top flange to create more compression strain could be a helpful mitigation strategy employed during transportation by bridge designers.
5. Selection by designers of more roll-tolerant girder cross-sections that have been developed considering transportation-related strains.
6. Future research should consider the following:
    - Measure the forces applied to girders through the jeep tongue using a variety of girder lengths.
    - Evaluate the effectiveness and safety of moving the rear jeep support closer to the girder midspan to reduce maneuvering stresses for long girders.
    - Use the existing research transportation records to develop a more sophisticated, non-linear model using advanced FEM software to aid in analytically evaluating girder performance.
    - Monitor additional girder transports to evaluate possible limitations on jeep tongue use or incorporation of temporary shipping prestressing installed on the girder top flange.
    - Develop a portable acceleration/roll monitor to be included with girder transport for the purposes of producing a transportation record of the girder for quality assurance purposes.
    - Investigate the possibility to move the rear trailer support inboard to allow tighter turn radii and minimize wheelbase.

IMPLEMENTATION

By identifying the loading effects caused by the rear jeep tongue on long, prestressed concrete girders during transport, the potential for cracking of these girders can be reduced. The link between the tongue forces and girder cracking had not been previously documented in published research. Through this research, recommendations to mitigate girder cracking during transportation were presented that include application of tongue forces by the designer during transportation stress evaluation and changes in transport procedures by the precaster.