Laboratory and Field Testing of an Accelerated Bridge Construction Demonstration Bridge: US Highway 6 Bridge over Keg Creek

tech transfer summary

April 2013

RESEARCH PROJECT TITLE
Laboratory and Field Testing of an Accelerated Bridge Construction Demonstration Bridge: US Highway 6 Bridge over Keg Creek

SPONSORS
Iowa Department of Transportation
Federal Highway Administration
(InTrans Project 11-411)

PRINCIPAL INVESTIGATOR
Brent Phares, Director
Bridge Engineering Center
Iowa State University
515-294-5879
bphares@iastate.edu

CO-PRINCIPAL INVESTIGATOR
Jon "Matt" Rouse, Assistant Professor
Civil, Construction, and
Environmental Engineering
Iowa State University

MORE INFORMATION
www.bec.iastate.edu

Bridge Engineering Center
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103
www.bec.iastate.edu

The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

IOWA STATE UNIVERSITY
Institute for Transportation

As a result of an aging infrastructure throughout the US, a need has arisen for the development of a fast, repeatable, and dependable way to replace "typical" bridges across the country.

Background

To address the need for the development of a fast, repeatable, and dependable way to replace "typical" bridges across the country, the Transportation Research Board (TRB) developed project R04, Innovative Designs for Rapid Renewal, as part of the Second Strategic Highway Research Program (SHRP 2). The goal of this project was to develop standardized accelerated bridge construction (ABC) systems for nationwide use (Iowa DOT 2011).

As part of the SHRP 2 Project R04, the Iowa Department of Transportation (DOT) was asked to select a demonstration bridge site to implement some of the ABC design concepts being developed.

The Iowa DOT selected a replacement bridge site in western Iowa on US Highway 6 over Keg Creek in Pottawattamie County. This site was selected due to the abundance of similar three-span bridges in Iowa and many other states. Bridge engineers wanted to ensure that what was learned from the R04 project would be applicable to future bridge projects (Iowa DOT 2011).

Research Description

The basic ABC concept employed in the Keg Creek Bridge project was to utilize prefabricated elements that are connected, in place, utilizing advanced material closure-pours and quick-to-install connection details.

First, it was desired to know more about the bond performance between the concrete deck high-performance concrete (HPC) and the closure pour material, ultra-high performance concrete (UHPC). Second, it was desired to understand how the completed bridge performed from a global and local perspective.

To answer the first question, a series of laboratory tests were conducted. To answer the second question, two live load tests were conducted on the completed bridge with one immediately following construction and one approximately seven months later.

Key Findings

As the bridge was being designed, simultaneous laboratory testing was being performed at Iowa State University of these transverse joints to be used. The results of these tests indicated special attention needed to be paid at these locations due to insufficient bond strength between the HPC and UHPC.

Through further laboratory testing of the bond strength at the HPC/UHPC interface, it is clear that there was cause for concern of opening at these interfaces. These concerns were reinforced by the findings in the comparison of the live load field tests.

Visual inspection, as well as evaluation of the collected data, showed a breakdown of the bond between the interface of the HPC and UHPC at the joints. The breakdown of this bond resulted in cracking of the deck allowing an ingress of road salts, which is verified by the presence of efflorescence on the underside of the bridge deck at joint interfaces.

Furthermore, the live load field testing was also used to quantify and compare global bridge behavior over a time period of approximately seven months. The overall behavior of the bridge was very similar from test to test with the exception of the breakdown of bond at the joint interfaces.

Bond Testing

- Testing of the bond in the laboratory indicated there is virtually no bond between precast HPC and UHPC when no surface preparation is implemented at the interface.
- Considering both the direct tension test and the simulated modulus of rupture (MOR) test, the most effective of the interface preparations was the use of a 3,000 psi pressure wash.
- All MOR average results fell below the estimated MOR of a 5,000 psi compressive strength HPC material (which was used in the Keg Creek Bridge), indicating the most likely location of cracking will be at the interface of the HPC and UHPC materials.
- Testing revealed a rather large variation in bond strength from sample to sample, indicating an inconsistency in bond development between the HPC and UHPC materials regardless of the interface preparation.
- UHPC maturity also affects the bond strength between the HPC and UHPC. The bond strength reaches a maximum value near the 7 day UHPC age and then decreases as the UHPC reaches the 14 and 28 day ages. This indicates a deterioration of bond over time.

Design Assumptions

- Lateral live load distribution factors for all modules were calculated to be much less than the 1.0 value used by the design engineer.
- Live load continuity between spans was verified by the strain reversal measured by the transducers mounted on the steel girders at midspan and also the negative moments seen at the east pier location.

Maximum Bridge Strains and Displacements

- The maximum recorded strains at the transverse joint away from the interface were well below the cracking strain for both the HPC and UHPC materials in both tests indicating cracking is unlikely at service level loads at these locations.
- The maximum recorded strains at the transverse joint across the interface of the HPC/UHPC were inconsistent when comparing north and south lines of instrumentation, while also being much greater than adjacent gauges along the north line. This result indicates an inconsistency in bonding of the different materials and points out a location of concern for cracking.
- The maximum recorded strains of the steel girders were significantly less than the yield strain of ASTM A709 Grade 50W steel at all instrumented locations (midspan, abutment, and pier) indicating yielding of the girders is unlikely at service level loads.
- The maximum recorded tensile strains of the pier cap in the 2011 test were greater than the cracking strain of the HPC material, which would be expected as the pier cap would be designed to crack.
- Maximum differential displacements between the HPC deck and UHPC longitudinal joint recorded in the 2012 test were effectively zero, showing no concern for excessive differential deflection.
- Maximum displacements across the interface of the pier cap to column connection of the east pier were minimal in both tests, showing no evidence for rocking of the pier cap in either the transverse or the longitudinal direction.

Comparison of Pseudo-Static Live Load Tests

- In general, the behavior of the bridge is very similar between the 2011 and 2012 tests with the exception of strains across the interface between the HPC deck and UHPC transverse joint and strains of the steel girders at the pier.
- Maximum strains across the interface of the HPC deck and the UHPC transverse joint increased significantly between the 2011 test and 2012 test indicating a loss of bond and potential cracking, which was confirmed through visual inspection of the joint.
- Maximum compressive strains in the bottom flange of the girders at the pier see a noticeable reduction in value from the first to second test, indicating a reduction in negative moment and implying a loss of continuity, to some degree, between spans. This result would be expected with the deterioration of the bond between the HPC deck and the UHPC transverse joint.
- Neutral axis depths calculated from the strains recorded at the midspan location of the steel girders most directly underneath specified load paths resulted in neutral axes located above the elevation of the concrete deck consistently for both tests.

Implementation Benefits and Readiness

The use of moment-resisting transverse UHPC joints at pier locations in the Keg Creek Bridge was a first for the US and is one of many concepts being employed to reduce road closure time as part of the development of ABC practices to be used throughout the country. Utilizing these technologies, road closure was reduced from an entire construction season to only two weeks.

Reference

Iowa DOT. 2011. US 6 Bridge over Keg Creek: Project Information. Office of Bridges and Structures. http://www.iowadot.gov/us6KegCreek/projectinfo.html.