Laboratory Investigation of Grouted Coupler Connection Details for ABC Bridge Projects

tech transfer summary

With an ever increasing desire to utilize accelerated bridge construction (ABC) techniques, it is becoming critical that bridge engineers, designers, and contractors have confidence in typical connection details that are utilized on precast concrete elements.

Background

Advancements and increased use of accelerated bridge construction (ABC) often result in the use of newly developed, or modified, technologies and/or construction techniques that are sometimes untested in this new application. For designers and engineers to confidently make use of these technologies and construction methodologies, evaluation of their performance relative to design assumptions, short- and long-term durability, and other performance-based metrics is required in laboratory tests.

One particular technology that has been transferred and utilized in several ABC projects are grouted reinforcing steel couplers. One specific project in particular, the Keg Creek Bridge on US 6 in Iowa, utilized grouted reinforcing steel couplers to connect drilled shafts to prefabricated pier columns and then the pier columns to prefabricated pier caps.

Problem Statement

Although their use has become more common in ABC projects, none of the testing of the grouted couplers was directly transferrable to these ABC applications and, as such, questions had been raised regarding their durability and performance in these real world applications. Following the Keg Creek Bridge project, the Iowa Department of Transportation (DOT) initiated a project to evaluate the grouted reinforcing steel couplers using connection details similar to those used on the Keg Creek Bridge.

Previous research and testing on these types of couplers has largely focused on the direct tension strength of the coupled reinforcing steel connection. In the case of the Keg Creek Bridge, the grouted couplers were utilized in areas were the primary loading on them would be axial compression from dead and live loads, and bending due to thermal loads and live loads.

Coupler specimen setup for four-point bending fatigue testing

August 2015

RESEARCH PROJECT TITLE
Laboratory Investigation of Grouted Coupler Connection Details for ABC Bridge Projects

SPONSORS
Federal Highway Administration
Iowa Department of Transportation
(InTrans Project 12-441)

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

CO-PRINCIPAL INVESTIGATOR
Travis K. Hosteng, Director and Bridge Research Specialist
National Center for Wood Transportation Structures and Bridge Engineering Center
Iowa State University
kickhos@iastate.edu

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

SPR RB07-013

Project Scope

The scope of work for this project incorporated a laboratory evaluation of full-scale specimens to evaluate the structural performance of a connection detail utilizing grouted reinforcing steel couplers, and specifically the magnitude of the crack width that develops under load and how well the crack closes after removal of the load. Performance metrics included validation of design assumptions related to strength, but centered on the durability of the connection for both short and long-term performance.

Research Description and Key Findings

Seven large specimens were cast utilizing two #14 epoxy-coated grouted reinforcing steel couplers, specifically Dayton Superior Sleeve-Lock couplers, per specimen and tested in a four-point bending configuration with the coupled reinforcing steel in the tension region of the specimen; six of the specimens were tested statically and the last specimen specimens was tested in fatigue.

Formwork, reinforcing cage, and #14 bars and couplers for laboratory specimens during construction

Sleeve-lock seal plugs were used on protruding reinforcing steel to keep bedding grout from entering couplers, grout was placed on top of the bottom specimen, and top specimen was carefully lowered on top

Static four-point bending test with applied axial load: specimen in the test frame setup with axial load applied with post-tension rods

Specimens 1 through 3 were all load tested to a peak load of approximately 360 kips with no axial load applied to the specimens. Specimens 4 and 5 were then tested with axial loads of 54 kips and 115 kips, respectively, applied to simulate loading of the columns/connections in the Keg Creek Bridge. Overall, static testing validated the design assumptions and provided good correlation to empirical calculations utilized during design of the specimens.

Specimens 1 through 5 were erected using the same grout for the grout bed as was used on the Keg Creek Bridge, W. R. Meadows 588-10k. Further evaluation of the data from the first five specimens indicated that the applied axial load on the specimens had a minimal effect on the performance of the grouted reinforcing steel coupled joints when loaded in bending. For both the case of a non-axially loaded and axially loaded specimen, the initiation of the crack at the grout interface was almost immediately upon loading.

The last specimen tested in static bending was Specimen 6. This specimen was fabricated using ultra-high performance concrete (UHPC) as the bedding grout and an axial load of 54 kips to allow for comparison with the previously tested Specimen 4. Like the first five specimens, Specimen 6 was loaded to approximately 360 kips and the grout joint monitored.

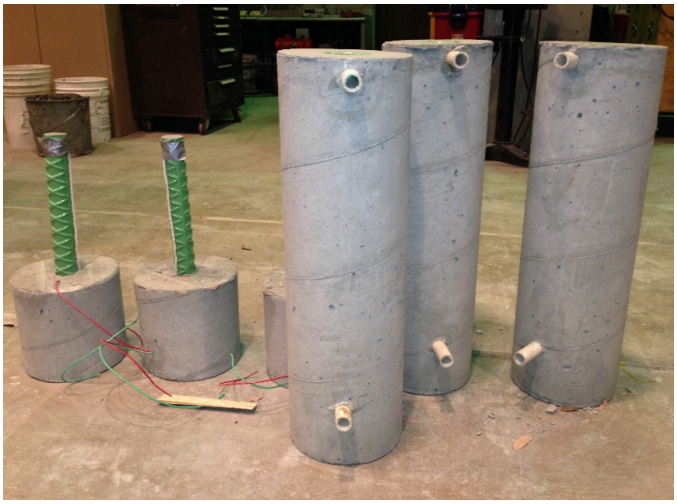
Based on test data, initiation of the crack at the grout interface for Specimen 6 using the UHPC occurred at an applied moment of approximately 13 ft-k. This suggests that use of UHPC for the bedding grout in this application would slightly delay the initiation of cracking of the joint. However, there was no improvement in the degree to which the crack closed upon unloading or the magnitude of the crack width during loading when compared to Specimens 1 through 5.

Typical cracks during loading of specimen with standard grout (left) and specimen using UHPC (right)

The last specimen, Specimen 7, was tested in fatigue to approximately 1 million cycles using a point load of 106 kips. This was the point load calculated to produce the 18 ksi stress in the coupled #14 bars specified by the 2010 American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Specification.

The fatigue test data indicated a maximum global displacement of approximately 0.18 in., which was consistent throughout the duration of the testing. Likewise, the crack width at the grouted interface remained relatively constant during the 1 million cycles and never exceeded 0.02 in.

Specimens were also evaluated for their ability to resist the intrusion of water and chlorides because chloride penetration resistance is an important criterion for coupled connections on bridges, especially in areas below expansion joints at the abutments and piers such as on the Keg Creek Bridge.



Small grouted coupler specimens for chloride penetration testing prior to grouting

Three additional small specimens were cast, each with one #14 grouted coupler cast into an 8 in. diameter sonotube to provide a minimum of 2 in. of clear cover around the circumference of the coupler. Another 8 in. diameter cylinder with a protruding #14 bar was then grouted to the section with the coupler. The reinforcing steel in these three specimens were outfitted with corrosion wire and submerged in a 3 percent chlorine bath to just above the grouted joint.

The specimens were allowed to soak for approximately 6 months with periodic readings taken on the corrosion wire. Because the grouted joints were uncracked, and the reinforcing steel was epoxy coated, no evidence of corrosion was seen during the testing of these specimens.

Small grouted coupler specimen for chloride penetration testing after grouting

Implementation Readiness and Benefits

Grouted reinforcing steel couplers have received considerable attention because they allow a quick and relatively easy means to connect precast concrete elements. The use of this technology was one of the many critical elements that allowed the construction of the Keg Creek Bridge to be completed with less than two weeks of road closure.

Bridge engineers, designers, and contractors now recognize the benefits of using grouted reinforcing steel couplers to accelerate the speed of construction, increase productivity, and simplify design details. The results of this study are intended to help in using these technologies and construction methodologies more confidently when designing and building ABC bridges with grouted reinforcing steel coupler connections that are sustainable, durable, and low-maintenance.