Iowa State University
Digital Repository

Tech Transfer Summaries | Institute for Transportation

12-2014

Investigation of Field Corrosion Performance and Bond/Development Length of Galvanized Reinforcing Steel

Brent M. Phares
Iowa State University, bphares@iastate.edu

Yoon-Si Lee
Bradley University, ylee2@bradley.edu

Brian Keierleber
Buchanan County, Iowa, bkeierleber@co.buchanan.ia.us

Jack Hupp
Iowa State University

Anurag Samudrala
Iowa State University

Follow this and additional works at: http://lib.dr.iastate.edu/intrans_techtransfer

Part of the Civil Engineering Commons

Recommended Citation

Phares, Brent M.; Lee, Yoon-Si; Keierleber, Brian; Hupp, Jack; and Samudrala, Anurag, "Investigation of Field Corrosion Performance and Bond/Development Length of Galvanized Reinforcing Steel" (2014). *Tech Transfer Summaries*. 42.
http://lib.dr.iastate.edu/intrans_techtransfer/42

This Report is brought to you for free and open access by the Institute for Transportation at Iowa State University Digital Repository. It has been accepted for inclusion in Tech Transfer Summaries by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.

Investigation of Field Corrosion Performance and Bond/Development Length of Galvanized Reinforcing Steel

Abstract

In reinforced concrete systems, ensuring that a good bond between the concrete and the embedded reinforcing steel is critical to long-term structural performance. Without good bond between the two, the system simply cannot behave as intended. The bond strength of reinforcing bars is a complex interaction between localized deformations, chemical adhesion, and other factors. Coating of reinforcing bars, although sometimes debated, has been commonly found to be an effective way to delay the initiation of corrosion in reinforced concrete systems. For many years, the standard practice has been to coat reinforcing steel with an epoxy coating, which provides a barrier between the steel and the corrosive elements of water, air, and chloride ions. Recently, there has been an industry-led effort to use galvanizing to provide the protective barrier commonly provided by traditional epoxy coatings. However, as with any new structural product, questions exist regarding both the structural performance and corrosion resistance of the system. In the fall of 2013, Buchanan County, Iowa constructed a demonstration bridge in which the steel girders and all internal reinforcing steel were galvanized. The work completed in this project sought to understand the structural performance of galvanized reinforcing steel as compared to epoxy-coated steel and to initiate a long-term corrosion monitoring program. This work consisted of a series of controlled laboratory tests and the installation of a corrosion monitoring system that can be observed for years in the future. The results of this work indicate there is no appreciable difference between the bond strength of epoxy-coated reinforcing steel and galvanized reinforcing steel. Although some differences were observed, no notable difference in either peak load, slip, or failure mode could be identified. Additionally, a long-term monitoring system was installed in this Buchanan County bridge and, to date, no corrosion activity has been identified.

Keywords

Bonding and joining, Bond strength, Epoxy coatings, Galvanized metals, Portland Cement Concrete, Reinforced concrete bridges, Buchanan County (Iowa)

Disciplines

Civil Engineering

Comments

The related 39-page final report is also available in this repository, under the same title.

This report is available at Iowa State University Digital Repository: http://lib.dr.iastate.edu/intrans_techtransfer/42

Investigation of Field Corrosion Performance and Bond/Development Length of Galvanized Reinforcing Steel

tech transfer summary

The work completed in this project sought to understand the structural performance of galvanized reinforcing steel as compared to epoxy-coated steel and to initiate a long-term corrosion monitoring program.

December 2014

RESEARCH PROJECT TITLE
Investigation of Field Corrosion Performance and Bond/Development Length of Galvanized Reinforcing Steel

SPONSORS
Iowa Highway Research Board (IHRB Project TR-666)
Iowa Department of Transportation (InTrans Project 13-481)
Federal Highway Administration

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

CO-PRINCIPAL INVESTIGATORS
Brian Keierleber, Buchanan County Engineer, Buchanan County, Iowa

Junwon Seo, Research 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.

The sponsors of this research are not responsible for the accuracy of the information presented herein. The conclusions expressed in this publication are not necessarily those of the sponsors.

IOWA STATE UNIVERSITY
Institute for Transportation

Background

In reinforced concrete systems, ensuring that a good bond between the concrete and the embedded reinforcing steel is critical to long-term structural performance. Without good bond between the two, the system simply cannot behave as intended.

The bond strength of reinforcing bars is a complex interaction between localized deformations, chemical adhesion, and other factors. Coating of reinforcing bars, although sometimes debated, has been commonly found to be an effective way to delay the initiation of corrosion in reinforced concrete systems.

For many years, the standard practice has been to coat reinforcing steel with an epoxy coating, which provides a barrier between the steel and the corrosive elements of water, air, and chloride ions.

Problem Statement

Recently, there has been an industry-led effort to use galvanizing to provide the protective barrier commonly provided by traditional epoxy coatings. However, as with any new structural product, questions exist regarding both the structural performance and corrosion resistance of the system.

Goal and Objectives

The primary objectives of this study were to investigate the difference in bond strength and development length between galvanized reinforcing steel and epoxy-coated bars by means of beam end tests and to instrument a bridge with sensors to evaluate, over long periods of time, the field performance of the galvanized reinforcing steel used in the bridge.

This study was not intended to define a new design method or an independent relationship for each specimen tested. It was intended to compare, in a relative manner, the bond strength of concrete-to-galvanized reinforcing steel to concrete-to-epoxy-coated bars.

The field monitoring portion of this project was not intended to provide any immediate answers regarding the corrosion resistance of galvanized reinforcing steel. Rather, the intent of this portion of the project was to take advantage of a unique opportunity to monitor the corrosion resistance of galvanized reinforcing steel using the construction of this demonstration bridge.

Research Description

In the fall of 2013, Buchanan County, Iowa constructed a demonstration bridge in which the steel girders and all internal reinforcing steel were galvanized. The research being reported at this point utilizing this demonstration bridge consisted of a series of controlled laboratory tests and the installation of a corrosion monitoring system that can be observed for years in the future.

Laboratory Testing

The laboratory testing program was carried out to evaluate and compare the bond strength of galvanized reinforcing steel to that of epoxy-coated bars. The bond strength of reinforcing steel was investigated by using beam end specimens with various bar sizes.

The evaluation process was based on the ASTM A 944 test protocols. To perform the beam end tests, 18 specimens—9 with galvanized test bars and 9 with epoxy-coated test bars—were constructed. The load at failure and the slip at the loaded and unloaded ends were noted and analyzed with the help of linear variable differential transformers (LVDTs).

Field Monitoring

In the field monitoring, 10 galvanized reinforcing bars in the bridge deck were instrumented with embeddable corrosion sensors and data were collected occasionally to assess their performance in terms of their corrosion resistance.

Key Findings

A total of 18 specimens were tested and the results from load-slip measurements were used as an indication of the variation in bond strength. The following conclusions were made based on the laboratory test results:

- The bond behavior of the galvanized reinforcing steel was similar to that of the conventional epoxy-coated bars. The difference in bond strength between them was not significant.
- In general, #8 and #10 galvanized reinforcing bars had an average bond strength that was greater than that of the same-sized epoxy-coated bars. Although this may indicate that galvanized steel could potentially be an adequate replacement for epoxy-coated bars, this may be disputed based on the test results on the slip at failure.
- The force reduction after reaching the peak load was abrupt for the specimens with poor concrete consolidation, whereas, it was gradual for other specimens.
- The during- and post-test observation revealed that the failure was by typical splitting and putout mode for most specimens.

The results of this work indicate there is no appreciable difference between the bond strength of epoxy-coated reinforcing steel and galvanized reinforcing steel. Although some differences were observed, no notable difference in either peak load, slip, or failure mode could be identified. In addition, no corrosion activity has been identified to date using the long-term monitoring system installed in this bridge.

Implementation Readiness and Benefits

A field monitoring program was successfully initiated that will allow the future corrosion performance of this bridge to be monitored. Additional monitoring will be conducted on an as-needed basis.

While the results of this study could be used as a foundation for understanding the bond strength of galvanized steel reinforcement in concrete compared to that of conventional epoxy-coated steel bars, a further study with a larger pool of specimens is needed for producing more reliable results.

A more in-depth investigation regarding the bond properties may also be needed before the use of galvanized reinforcing steel is considered and incorporated into the Iowa Department of Transportation's current design codes.

In such a study, the parameters or variables to be considered may include test bar location, embedment and/or splice length, amount of transverse reinforcing steel, size of concrete specimens, coating thickness, etc. In addition, large-scale flexural beam tests may allow for establishing deflection and cracking behavior of beams reinforced with galvanized reinforcing steel.

With regard to corrosion performance, it is recommended that an accelerated corrosion study be conducted. With such a study, the corrosion performance of galvanized reinforcing steel can be made in a matter of months rather than decades. Such studies have been completed successfully on other corrosion-resistant reinforcing steel.