Evaluation of the Performance of A1010 Bridge Steel

tech transfer summary

January 2020

RESEARCH PROJECT TITLE
Evaluation of the Performance of A1010 Bridge Steel

SPONSORS
Iowa Department of Transportation
(InTrans Project 16-562)

PRINCIPAL INVESTIGATOR
Brent Phares, Research Associate Professor
Bridge Engineering Center
Iowa State University
bphares@iastate.edu / 515-294-5879
(orcid.org/0000-0001-5894-4774)

MORE INFORMATION
intrans.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

The results of this work showed that ASTM A1010 steel has satisfactory structural and fatigue performance for bridge girders and began an investigation into the potential for galvanic corrosion over time when different fastener types are used next to A1010 steel components.

Goals

- Evaluate the fundamental behavior of girders fabricated using ASTM A1010 steel
- Assess the in situ performance of a four-span bridge constructed with two A1010 steel girders and two ASTM A709 weathering steel girders
- Begin the evaluation of the potential for galvanic corrosion over time when different fastener types are used next to A1010 steel

Background

A1010 steel is relatively new to the market of structural stainless steel and is a nominal 12% chromium (10.5% minimum, 12.5% maximum) material that is reported to have enhanced corrosion resistance over that of traditional painted structural steel, weathering steel, and galvanized steel. When this project started, only six A1010 steel bridges had been built in the US.

Problem Statements

Despite the wealth of information on the durability of A1010 steel in corrosive environments, the literature had a gap concerning how this type of steel responds to the loads that bridge structures experience during their service lives.

In addition, while several researchers have recently focused on investigating the general accelerated uniform corrosion and galvanic corrosion properties of A1010 steel, additional tests of galvanic corrosion may be essential for A1010 steel in contact with dissimilar metals at in situ bridge sites.

Salix Interchange Bridge on County Road K25 over I-29 in Woodbury County, Iowa

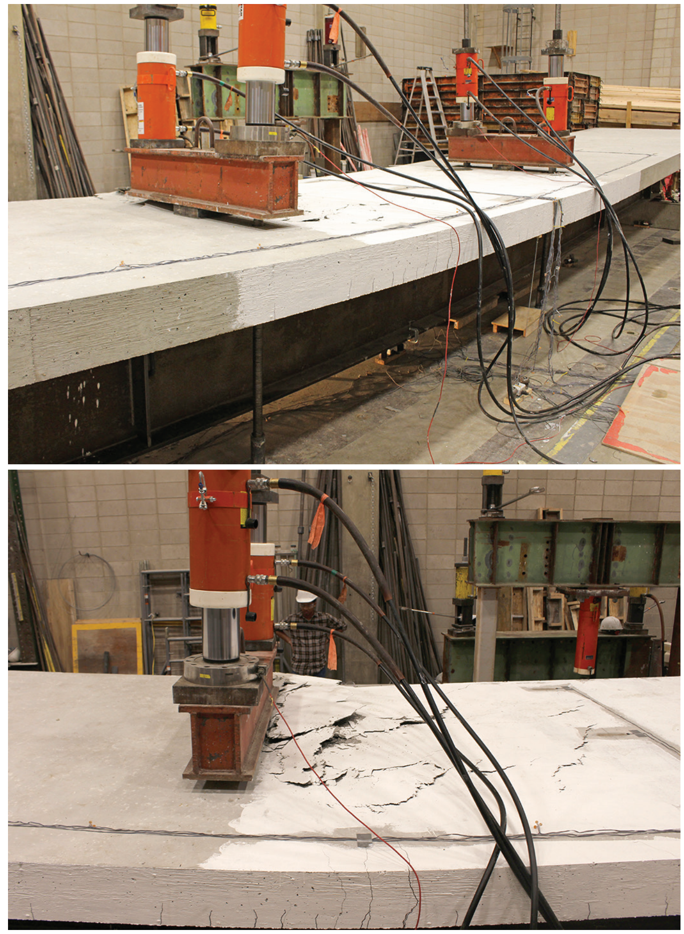
Research Description and Methodology

In 2016, the Iowa Department of Transportation (DOT) replaced a bridge in Woodbury County (on County Road K25 over I-29 at the Salix interchange) with a two-lane, four-span, continuous, steel-girder bridge partially constructed using ASTM A1010 bridge steel, i.e., for the two southernmost girders.

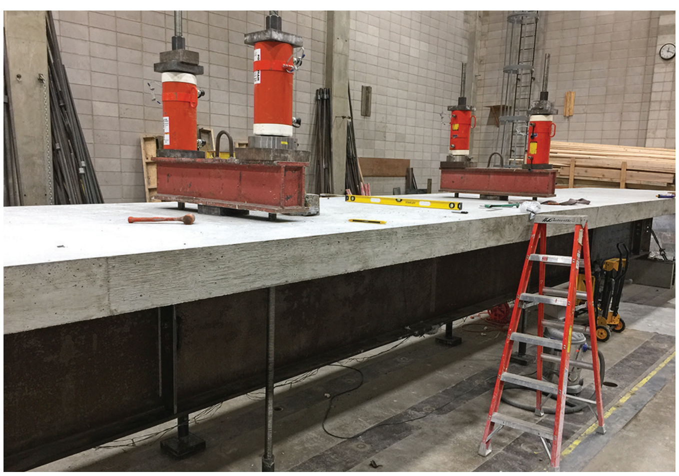
A comprehensive experimental program was carried out to investigate the performance of A1010 steel under a four-point bending scenario to determine the plate girder and composite flexural behavior.

A 52 ft 9 in. long A1010 steel girder like the two used in the bridge was designed, fabricated, and laboratory tested, with the results also compared to the current American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications. Additionally, tensile and fatigue tests were conducted to obtain the mechanical and fatigue behavior for the A1010 steel.

Cyclic material tests were carried out on coupon samples to investigate the high-cycle fatigue properties for A1010 steel. The stress-life method was adopted to predict the fatigue life for A1010 steel, and the predicted S-N curve (a log-log plot of stress range versus the number of cycles to failure) for A1010 steel was compared to other steel, including A709 weathering steel and A7 steel.



Ultimate flexural performance testing for the A1010 specimen



Loading setup for composite beam under 50% yield moment

Coupon sample specimens for fatigue testing

Two field tests for the Woodbury County (Salix Interchange) Bridge, which was designed utilizing A1010 steel and A709 weathering steel girders, were conducted with the goal of characterizing the difference in responses between the two types of steel.

Instrumented live-load tests on the bridge were conducted to identify any changes in behavior that occurred with time. The data were also analyzed for differences in response between the A1010 and A709 steel girders.

To characterize the behavior of galvanic corrosion of the A1010 steel in contact with other metal, this study implemented galvanic corrosion evaluation testing on a full-scale girder cross frame and also on an exposed A1010 steel plate at the bridge site.

Girder cross frame specimen for galvanized corrosion monitoring with galvanized steel bolts on the left and stainless steel bolts on the right

Instrumenting the girders for the live load tests

A1010 steel plate with stainless steel and galvanized steel bolts and welded connection

Live-load testing on the bridge

Both of these test specimens were constructed using different types of steel bolts and welds for comparison purposes, and corrosion testing on them will be ongoing.

Key Findings and Conclusions

- The predictions obtained utilizing actual material properties were reasonable compared to the results obtained from the laboratory test, indicating the A1010 girder's ability to meet the AASHTO design requirements. When the designed material properties were utilized for hand calculations, the flexural capacity measured from the laboratory test was 15.4% higher. This may be due to the difference between the material properties of A1010 steel obtained from tensile tests and the recommendations in design.

- In the fatigue tests of coupon samples, A709 steel showed a slightly higher fatigue resistance in the high-cycle fatigue region compared to A1010 steel. Both A1010 and A709 steel exhibited higher fatigue resistance than A7 steel, which may be caused by the difference in their strength. However, the fatigue limit for A1010 steel was found to be between 37.4 ksi and 40.8 ksi in the laboratory testing, indicating A1010 steel can provide adequate fatigue resistance according to current fatigue design provisions.
- The calculated distribution factors from the measured field strains and the AASHTO-recommended equations were investigated for comparison, and, for all cases, the maximum measured distribution factors were less than those calculated using the equations.
- In general, the results showed that the changes of structural performance for the girders when subjected to static live load tests over the two years were minimal.

Future Work

Further field studies are being conducted to evaluate the potential for galvanic corrosion when different types of bolts and welds are used next to A1010 steel:

- Long-term observational monitoring of galvanic corrosion on the full-scale cross frame will collect data for two types of bolted connections: stainless and galvanized steel.
- Likewise, long-term monitoring of the A1010 steel plate placed at the bridge site will be conducted and periodically documented for the development of corrosion.

Implementation Readiness and Benefits

- In general, there were no apparent differences observed between A1010 and A709 girders during field testing. It was concluded that the A1010 steel shows satisfactory structural and fatigue performance.
- A1010 steel can provide adequate fatigue resistance according to current fatigue design provisions.
- The longer term galvanic corrosion testing results will be documented and shared in the future. The results of this work will help in understanding the importance of controlling and reducing galvanic corrosion for future A1010 steel bridges located in the region.

Recommendations for Additional Future Research

The following recommendations are provided for future study based on the observations from this project:

- Long-term monitoring of galvanic corrosion behavior may be necessary to be performed for A1010 welded connections.
- High-cycle fatigue investigations may also be desired in the future for A1010 steel bolted and welded connections.