Evaluation of the Performance of A709 Grade 65 QST Bridge Steel

tech transfer summary

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RESEARCH PROJECT TITLE
Evaluation of Performance of A709 Grade QST 65 Steel

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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.

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This project evaluated the efficacy of using A709 Grade QST 65 steel for bridge projects and found that the performance requirements were met and surpassed and that it was also cost effective.

Project Goal

The primary goal of this project was to evaluate the efficacy of A709 Grade quenching and self-tempering (QST) 65 steel for use in Iowa bridge projects.

Research Objectives

- Identify the current state of use of A709 Grade QST 65 steel in bridge projects
- Identify the ductility and strength characteristics of A709 Grade QST 65 steel through full-scale laboratory testing
- Identify the fatigue characteristics of A709 Grade QST 65 steel through cyclic fatigue testing
- Observe and compare bridge construction similarities and differences to conventional steel construction using the new bridge planned over Sand Creek in Buchanan County, Iowa
- Compare relative costs of using A709 Grade QST 65 steel versus conventional steel
- Measure the live load response at various points in time on the Sand Creek Bridge constructed using A709 Grade QST 65 steel

Problem Statement

Over the course of history, steel grades have continually been modified and improved with the intention of addressing specific applications. In most cases, the strength and ductility of steel is improved. The adaptation of new steel grades can be slow-going as the first projects are completed and the use of non-conventional steels are proven.

First bridge project in the US utilizing A709 Grade QST 65 steel: Buchanan County Sand Creek Bridge

With any new material, questions frequently arise about how a structure designed with the material will meet current design assumptions and provisions. Only recently has this steel been adopted for use in the *Standard Specification for Structural Steel Bridges* (ASTM 2018) under the name A709 Grade QST 65.

In many ways, testing of new materials is simply needed to convince engineering staff of the material's efficacy and performance. It is very likely that some of the same benefits realized with this steel in vertical building construction can be realized in bridge construction. For that reason, appropriate testing and demonstration projects are needed to prove the efficacy of this steel for bridge construction.

Background

A913 Grade 65 steel has been used within building structure design since 1995 when it was included in the American Institute of Steel Construction (AISC) *Manual of Steel Construction*. The grade was developed in Europe in the late 1970s and 1980s and became more readily used in the early 1990s.

The benefits (reduced structure weight, increased strength and ductility, etc.) are proven within the building industry.

US-based Nucor-Yamato Steel Company became the first domestic producer of this grade of steel in 2016. At the end of 2018, Nucor-Yamato received approval to include ASTM A913 into the ASTM A709-18 *Standard Specification for Structural Steel Bridges*.

Under the A709 specification, and for reference to bridge steels, A913 Grade 65 is listed as A709 Grade QST 65. A709 Grade QST 65 steel is a high-strength, low-alloy structural steel produced using the quenching and self-tempering process.

Put simply, after the rolling process, the steel surface is cooled with water jets while the temperature of the core remains high. The high core temperature then reheats the surface, which is the self-tempering process. The result is a hardened surface with a ductile core.

Research Description

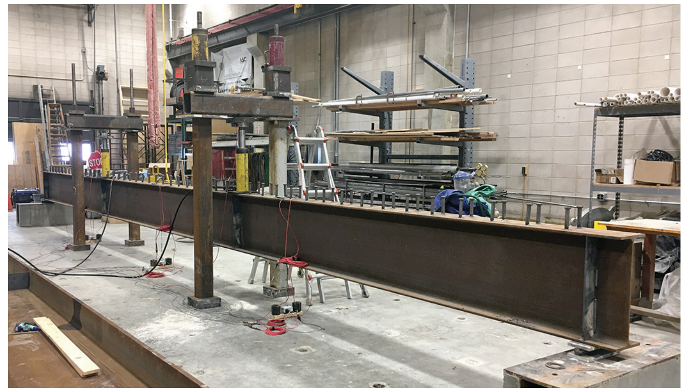
The ductility and strength of the material was observed through the various laboratory tests completed for this project as well as the testing performed by others.

In total, four laboratory load tests were completed using two full-scale sized beams in a non-composite and composite configuration.

In each case, customary steel deflection calculations were completed to predict and compare to the behavior of the beams under four-point loading.

Fatigue tests were completed in the laboratory to determine the relationship between cyclic stress amplitudes and the number of cycles to failure.

Lastly, three live load bridge tests were completed about one year apart. The data were compared to identify whether any behavioral changes had occurred in the bridge and, if changes had occurred, whether any were directly attributable to the steel.

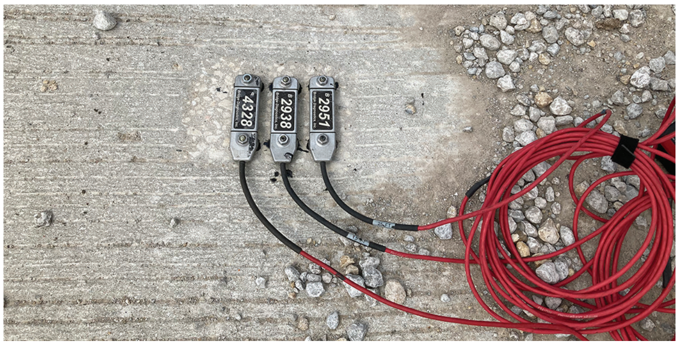


Full-scale W24×68 non-composite load test setup in the laboratory

Full-scale W30×173 composite beam test setup in the laboratory

First of the three load test vehicles on the approach to the Sand Creek Bridge about one year apart

Sand Creek Bridge strain gauges at midspan



Sand Creek Bridge strain gauges for top of deck strain values

Key Findings

- The non-composite and composite beams performed very closely to the predicted elastic behavior with respect to strain and deflection measurements during the laboratory load tests.
- The yield strength of the steel was found to be approximately 72 ksi and 75 ksi for the W30×173 beam and W24×68 beam, respectively.
- Tensile coupon tests resulted in a yield strength of 69.0 ksi.
- Fatigue tests were completed and the fatigue limit was found to be between 34.50 ksi (largest stress magnitude with no failures) and 37.95 ksi (smallest stress amplitude with failures).
- The modified design of this first-in-the-nation bridge using Grade QST 65 steel over Sand Creek allowed for a reduction in beam size for this relatively short-span, low-traveled bridge due to the increased strength of the steel beams.
- As a secondary advantage, 3 in. of additional vertical channel clearance was gained for the Sand Creek Bridge.
- The live load tests on the Sand Creek Bridge over three years indicated no change in the structural behavior.
- The results of this study indicate that the minimum requirements for this steel grade as documented in ASTM A709 were met and surpassed.

Cost Analysis Findings

- Currently, the cost of QST Grade 65 steel is nearly the same as that for 50 ksi steel with an approximate 3% premium, depending on the size requirements.
- Due to the lighter section size and near-equivalent steel price for each grade, a reduction in steel cost was realized.
- The total steel cost for the Sand Creek Bridge beams resulted in a 20% material cost savings.
- Overall, the material cost can be reduced when steel member sizes can be reduced as a result of the increased strength of QST Grade 65 steel.

Implementation Readiness and Benefits

A709 Grade QST steel is being increasingly used as a structural steel grade on projects throughout the US and Europe. Its higher strength advantages provide opportunities to minimize the structure required for a project using more traditional steel grades while maintaining the needed capacity.

Furthermore, now that the US has a domestic producer of this grade, the unit weight costs are comparable to traditionally used steel grades.

The researchers recommend considering the use of A709 Grade QST steel on bridge projects in Iowa due to its higher strength (30% increase in strength over 50 ksi steel) and suitable material characteristics. Potential cost savings may be realized, especially when the member yield strength controls and the size/weight can be reduced due to the higher strength characteristics of Grade QST steel.

The first-in-the-nation bridge using Grade QST 65 steel constructed over Sand Creek in Buchanan County is a relatively short-span, low-traveled bridge that has performed well since being put into service. The bridge performance and laboratory testing results should give confidence to engineers considering the use of this steel grade on projects with longer spans and higher traffic counts.

The researchers recommend incorporating this steel grade into the preliminary design of several bridge projects to get an assessment of potential structural changes and cost comparisons.

References

AISC. 1995. *Manual of Steel Construction*. American Institute of Steel Construction (AISC). Chicago, IL.

ASTM. 2018. *A709/A709M-18 – Standard Specification for Structural Steel Bridges*. ASTM International, West Conshohocken, PA.