Evaluation of the Performance of A709 Grade 65 QST Bridge Steel

Final Report
September 2022

BRIDGE ENGINEERING CENTER

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
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16. Abstract

The primary goal for this project was to evaluate the efficacy of A709 Grade QST 65 steel for use in Iowa bridge projects. The objectives of the project were as follows:

- 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 a 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, which was constructed using A709 Grade QST 65 steel

The ductility and strength of the steel was observed through the various laboratory tests completed for this project as well as the testing performed by others. Minimum requirements for this steel grade have been established, and the results of this study indicate that the requirements were met and surpassed.

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. The total steel cost for these beams resulted in a 20% material cost savings.

The results should give confidence to engineers considering use of this steel grade on bridge construction projects with longer spans and higher traffic counts.

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EVALUATION OF THE PERFORMANCE OF A709 GRADE 65 QST BRIDGE STEEL

Final Report
September 2022

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The research team would like to acknowledge the Iowa Highway Research Board (IHRB) and Iowa Department of Transportation (DOT) for sponsoring this research. They would also like to thank the technical advisory committee members for their guidance on this project and Nucor-Yamato Steel Company for supplying the beams for laboratory tests.

Additionally, the research team would like to thank Buchanan County engineers and maintenance personnel for arranging and participating in the live load tests on the Sand Creek Bridge.

Finally, the author would like to thank Doug Wood, Owen Steffens, and the numerous undergraduate students at the Structural Engineering Research Laboratory at Iowa State University for their work to construct and conduct the laboratory tests.

EXECUTIVE SUMMARY

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.

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.

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.

1 INTRODUCTION

1.1 Background and 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.

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

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. QST stands for quenching and self-tempering.

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.

1.2 Goals and Objectives of the Study

The primary goal for this project was to evaluate the efficacy of A709 Grade QST 65 steel for use in Iowa bridge projects. In particular, the objectives of this project were as follows:

- 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

1.3 Historical Significance of the Work

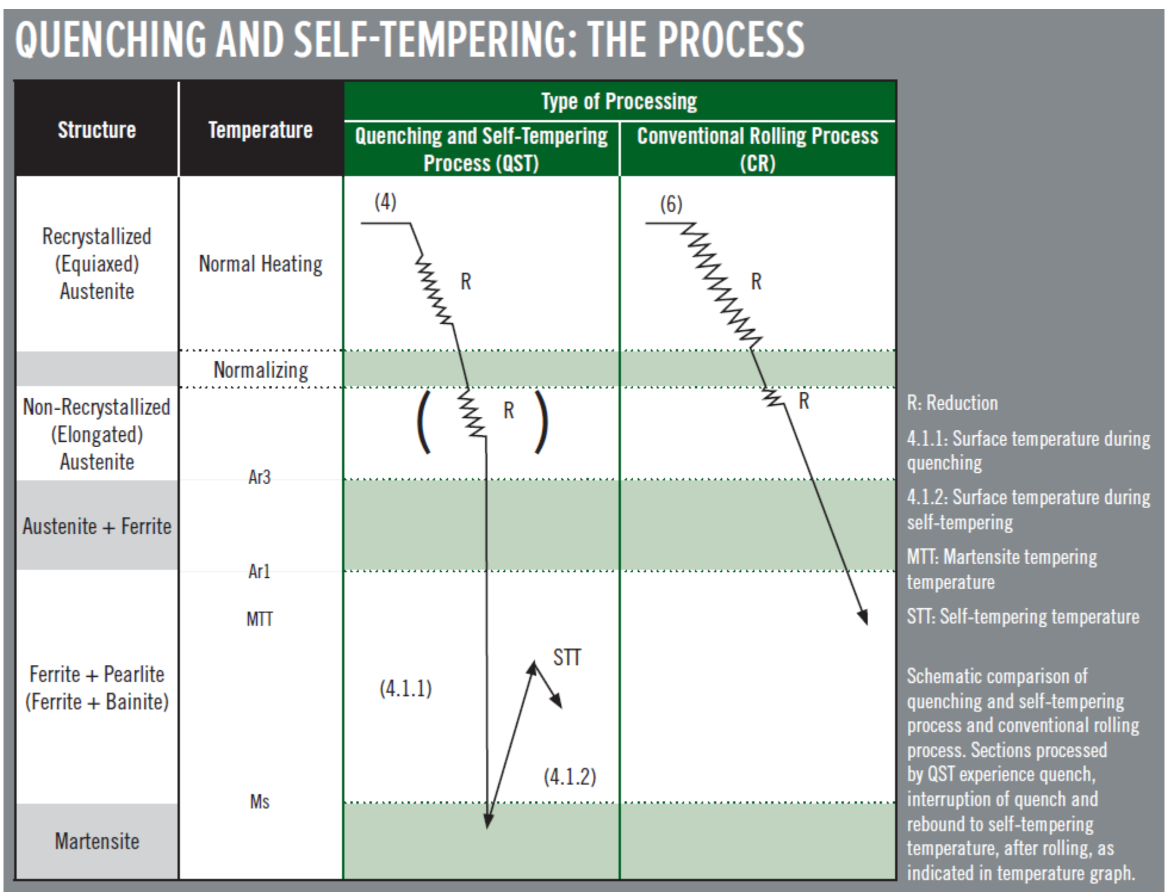
ASTM A913 steel has been included in the AISC *Manual of Steel Construction* since the mid-1990s and has been used in vertical building construction most often in recent decades. The grade was developed in Europe in the late 1970s and 1980s and became more readily used in the early 1990s. US-based Nucor-Yamato Steel Company became the first domestic producer of this grade 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.

With any new material, questions frequently arise about how a structure designed with the material will meet current design assumptions and provisions. In many ways, testing of new materials is simply needed to convince engineering staff of the material's efficacy and performance. The objective of this project was to further evaluate and characterize the material for use in bridge projects.

1.3.1 Steel Quenching and Self-Tempering Process

A709 Grade QST 65 steel is a high-strength, low-alloy structural steel produced using the quenching and self-tempering process (see Figure 1).



Nucor-Yamato 2019

Figure 1. Quenching and self-tempering process comparison

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.

The grade was first developed in Europe around the late 1970s and early 80s. It wasn't until 1995 that the grade was introduced to the American market when it was adopted into the AISC construction manual as ASTM A913 Grade 65 (see Figure 2).

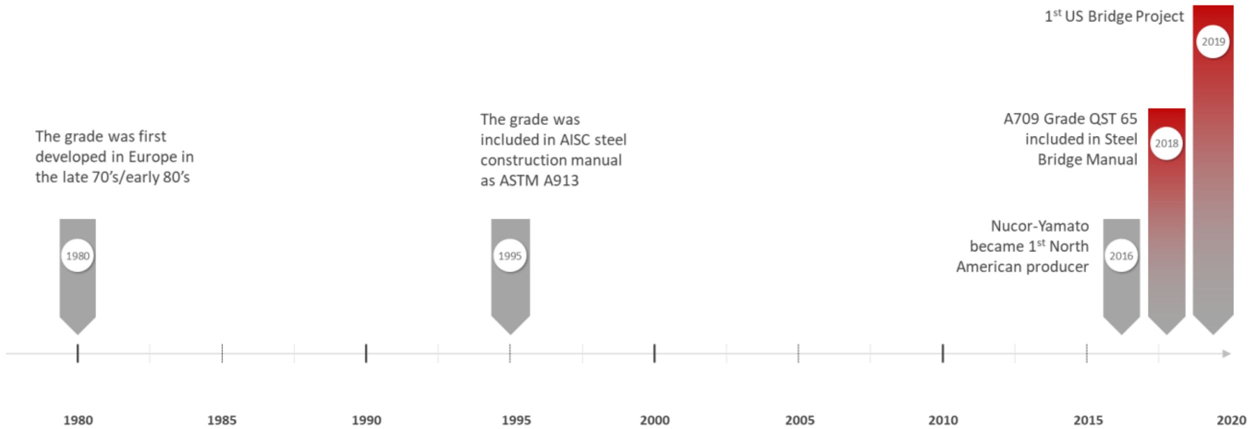


Figure 2. Historical timeline for Grade QST 65

A709 Grade QST 65 steel provided a design solution where high strength and ductility were desired, such as in seismic design. This grade has been used in building design under the name A913 and has proven useful in specific circumstances. However, it was not widely used because, until 2016, the US did not have a domestic producer of this grade.

In 2016, Nucor-Yamato became the first North American producer. Although this grade retained its A913 grade within the AISC *Manual of Steel Construction* in 2018, the material was adopted into the *Standard Specification for Structural Steel Bridges* as A709.

Some advantages over more conventionally used steels are as follows. First, the higher yield strength provides a 30% increase in strength over 50 ksi steel. Secondly, potential exists for cost savings. 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. 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.

1.3.2 The Sand Creek Bridge in Buchanan County

A real world bridge application now exists in Iowa. The Sand Creek Bridge in Buchanan County is the first bridge project in the US utilizing A709 Grade QST 65 steel.

This bridge was originally designed using W24×84 A992 Grade 50 beams. Four beams, 42 ft long and weighing 84 plf costing $45.50/hundred lbs resulted in a material cost of $6,400. The modified design, which used A709 Grade QST 65 steel, allowed for a reduction in beam size due to the increased strength. The new beam size was W24×68. The total steel cost for these beams was about $5,200, which resulted in a 20% material cost savings.

1.4 Research Tasks

The following tasks were completed to perform this work:

1.4.1 Task 1 – Literature Review

The research team gathered and reviewed available literature addressing the characteristics and performance of A709 Grade QST 65 steel. As a basis for evaluation, the gathered information was compared to more conventional steel grades. The team reviewed books, agency guidance manuals, technical reports, and manufacturer literature, together with papers published in journals and at scientific meetings. A particular focus was given to European literature as the European use of A709 Grade QST 65 steel is slightly more mature at this time.

1.4.2 Task 2 – Laboratory Testing

Laboratory testing was completed to verify current assumptions and provisions of a material not currently in standard use: A709 Grade QST 65 steel. Two beams were donated and shipped by Nucor-Yamato to the Iowa State University Structural Engineering Laboratory for subsequent testing. The first was a 42 ft long W24×68 exact replica of a girder being used in the new bridge construction project over Sand Creek in Buchanan County. The second was a 65 ft long W30×173.

To test each of these sections and their ability to meet American Association of State Highway and Transportation Officials (AASHTO) *Load and Resistance Factor Design (LRFD) Bridge Design Specifications* (BDS) (2020), the beams were tested with and without a composite concrete deck constructed on top of the beams. Testing was completed using a typical four-point bending configuration frequently utilized to evaluate bending behavior. This testing also sought to ensure the section had adequate ductility.

1.4.3 Task 3 – Fatigue Testing

Fatigue testing was completed with the objective to characterize fatigue behavior and predict fatigue life of A709 Grade QST 65 steel. Steel specimens were prepared and subjected to fatigue cycling up to 2,000,000 cycles or specimen failure, whichever came first. The results were compared to other more conventionally used steels including another new generation of steel known as A1010.

1.4.4 Task 5 – Onsite Construction Documentation

The new bridge in Buchanan County spanning Sand Creek was constructed using A709 Grade QST 65 steel girders. This project provided an opportunity to document any construction similarities or differences observed with respect to the differences in steel.

Due to the increased strength characteristics of A709 Grade QST 65 steel when compared to the A992 steel girders originally planned, a reduction in overall steel tonnage was realized. Additionally, where welding may have been required, opportunities for additional efficiencies existed. These, along with other observations and relative costs, were compared to the use of more conventional steels and were summarized.

1.4.5 Task 6 – Onsite Bridge Testing

After completion of construction, the Sand Creek Bridge was live load tested. Using numerous strain transducers attached to the superstructure, strain data were collected while a loaded truck of known weight and dimensions was driven across the bridge. About one and two years later, the test was repeated with similar data collected. The data were then compared to identify if any behavioral changes had occurred in the bridge, and, if so, whether any of the changes were directly attributable to the steel.

1.4.6 Task 7 – Final Report

A final report documenting the steps, outcomes, and recommendations of each task was completed following Iowa Department of Transportation (DOT) publication guidelines for research reports.

1.5 Report Overview

This report consists of six additional chapters and a References section.

- Literature Review (Chapter 2)
- Laboratory Testing and Test Results (Chapters 3 and 4, respectively)
- Fatigue Testing (Chapter 5)
- Field/Bridge Construction and Testing (Chapter 6)
- Summary, Conclusions, and Recommendations (Chapter 7)

2 LITERATURE REVIEW

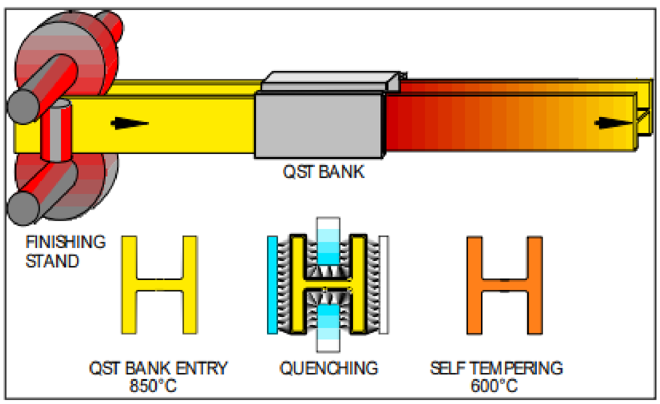
2.1 Recent History

Seeing potential advantages and applications, A709 Grade 65 QST has been recently adopted into the A709 *Standard Specification for Structural Steel Bridges* (ASTM A709 2018). Prior to this, the same steel grade has been used in the vertical building construction industry under the name A913 Grade 65. The advantages of this steel come in the form of weight reduction and, for seismic applications, the grade performs well for the "strong column-weak beam" design philosophy.

Until recently, the use of this steel in the US has been limited to specific applications given a domestic producer was not available to bring the cost in line with more commonly used steel grades. That is, the added cost did not always outweigh the structural benefit provided by A913/A709 Grade 65 QST steel.

2.2 Manufacturing Process

The manufacturing process, which is depicted in Figure 3, is similar to the rolling process of other standard steel grades (e.g., A992) with the exception of the additional QST process.



Shinde and May. 2012 and Weber and Cajot n.d.

Figure 3. Quenching and self-tempering process

Upon completion of the rolling process, the surface of the steel shape is immediately exposed to water jets (quenching) to quickly cool the outermost parts of the shape to a regulated temperature. Prior to the shape fully cooling, the exposure to the water is ceased allowing the core to re-heat the outer layers (self-tempering). The temperature prior to quenching is generally at about 1,560°F. Self-tempering occurs at about 1,100°F. The quenching and self-tempering process refines the steel microstructure, improving the yield and tensile strengths while maintaining the desired ductility and toughness.

2.3 Mechanical Properties

The higher yield and tensile strength of the Grade 65 QST steel is obtained through the formulaic composition of the steel and the manufacturing process. The chemical recipe requires less phosphorous, sulfur, and copper when compared to A992, which creates a less brittle section (specifically regarding phosphorous and sulfur) and enhances the quality and mechanical properties. When compared to the commonly used A992, Grade 65 QST provides a 30% increase in yield stress (65 ksi vs. 50 ksi) and a 23% increase in tensile stress (80 ksi vs. 65 ksi). A comparison of the maximum element content for Grade 65 QST and A992 steel is provided in Table 1.

Table 1. Chemistry comparison of Grade 65 QST and A992 steel

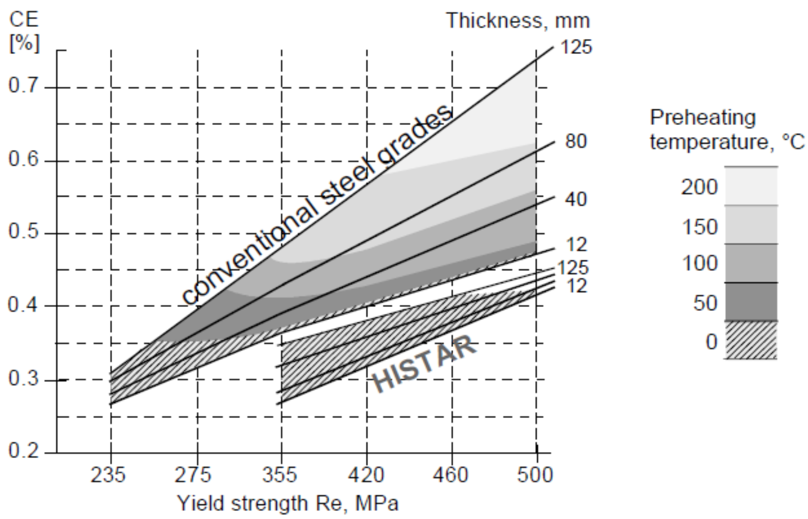
	Maximum Content (%)	
Element	**A709 Grade 65 QST**	**A992**
Carbon	0.12	0.23
Manganese	1.60	0.50 to 1.60
Phosphorous	0.03	0.035
Sulfur	0.03	0.045
Silicon	0.40	0.40
Copper	0.35	0.60
Nickel	0.25	0.45
Chromium	0.25	0
Molybdenum	0.07	0.15
Columbium	0.05	0.05*
Vanadium	0.08	0.15*
Iron	Remainder	Remainder

* vanadium (V) + niobium (Nb) not to exceed 0.15
Sources: ASTM A709, ASTM A992

2.4 Weldability

The weldability is not diminished in comparison to other common steel grades. In fact, Grade QST 65 has undergone significant testing and has been included in the American Welding Society (AWS) *D1.1 Structural Welding Code—Steel* (2002). It is qualified to be welded to other structural grades with welding procedure specifications fully developed for welding steels with dissimilar strengths. Even more, using Grade QST 65 does not require preheating, which can save time and expense where otherwise required. This should not be understated as it can result in potentially thousands of labor-hours being saved.

A large European steel manufacturer, ArcelorMittal, produced the graph shown in Figure 4.



$$CE\ (\%) = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Cu + Ni)}{15}$$

Weber and Cajot n.d.

Figure 4. Weldability of conventional steel grades and QST steel grades (HISTAR)

This graph directly compares the weldability of conventional steel grades and QST steel grades, known as HighStrength-ArcelorMittal (HISTAR) in the European and national standards, for structural steels. HISTAR 460 is the equivalent to Grade QST 65 in the US.

The range of yield strength shown is 235 MPa to 500 MPa (29 ksi to 73 ksi), and the thickness shown is 12 mm to 125 mm (0.5 in. to 5 in.). The required preheating temperature are indicated for each steel grade.

2.5 Toughness

After the brittle fracture failure of the Silver Bridge over the Ohio River between West Virginia and Ohio in 1967, the Charpy V-Notch (CVN) test became a common test to measure fracture toughness and was required in the 1969 10th edition of the AASHTO *Standard Specifications for Highway Bridges* for some steels, and for all steel grades in later editions.

ASTM A709 provides toughness levels for three temperature exposures and for two uses: non-fracture critical and fracture critical. This is different than the CVN requirements for the similar ASTM A913 Grade QST 65, which is simply 40 ft-lb absorbed energy at 70°F using the CVN impact test (ASTM A673 2017). Regardless, the reader should know that the toughness requirement of these steel grades is specified, and the attention given to improved toughness ultimately leads to reducing the susceptibility to brittle fracture.

2.6 Surface Protection

Hot-dip galvanizing (HDG) is often used to for the protection of steel members when subjected to environmental conditions. HDG can be used with Grade 65 QST steels despite some indication that fine-grained, high-yield-strength steels have a more critical behavior (embrittlement) during galvanization than conventional steels; the grain structure is so small that some of the absorbed hydrogen will remain trapped between the grains of the steel This is most common in steel grades with tensile strengths above 150 ksi (Langill 2004). It is improbably that steel grades with lower tensile strengths, such as Grade 65 QST, will not experience the same critical behavior. In fact, recent tests using HISTAR grades indicate the behavior during HDG is the same as that for conventional structural steels (Weber and Cajot n.d.).

2.7 Current Applications

Grade QST 65 steel has been an attractive alternative to conventional steels in certain applications. The advances made in metallurgy and manufacturing processes have made it possible to achieve greater structural strength using less material.

Most projects where Grade QST 65 steel has been used are buildings, where the steel grade has helped reduce column sizes, increase the span of long-span steel trusses, and in the design of structures in seismic regions (“strong column, weak beam” approach). A reduction in the required steel increases occupiable space and improves the overall energy usage from manufacturing to in-service.

Numerous high-profile building projects have benefitted from the structural capabilities of Grade QST 65 steel. The article by Millard (2022) highlights numerous marquee projects that have recently been constructed using Grade QST 65 steel.

3 LABORATORY TESTING

Four individual laboratory tests were completed as part of the scope of this research: two beams, W24×68 and W30×173, were tested in non-composite and composite configurations. Each beam was subjected to four-point bending tests, while deflection and strain data were collected over the duration of the tests. The W24×68 beam is the same size, shape, and length of the beams used on the Sand Creek Bridge, which was the first in the nation to use A709 Grade QST 65 steel girders.

3.1 Non-Composite Load Tests

The non-composite beam load tests were completed using a four-point bending loading scenario centered on the beam with 15 ft between point loads. The total clear span for the girders was 41 ft and 64 ft for the W24×68 and W30×173 beams, respectively. Applying equal loads at equal distances from the bearing points ensures the moment induced between point loads is constant (see Figure 5).

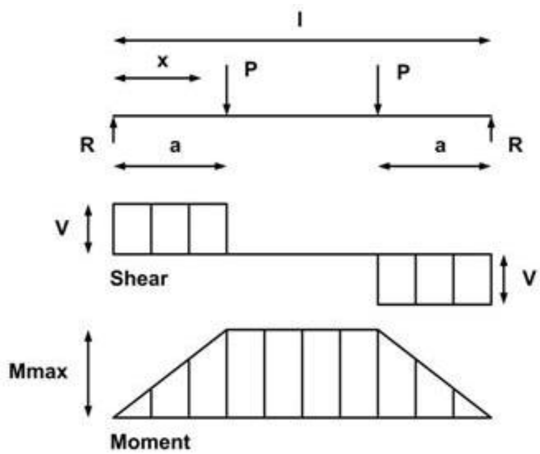


Figure 5. Simple beam with equal symmetric loads

The beams were instrumented with top and bottom flange strain gauges and displacement transducers at quarter spans and midspan. The test configuration is shown in Figure 6 and Figure 7 for the W24×68 beam and W30×173 beam, respectively.

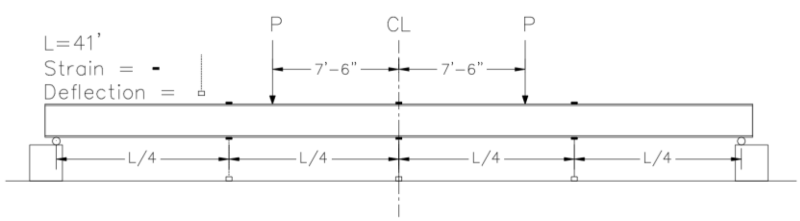


Figure 6. W24×68 non-composite bending test configuration

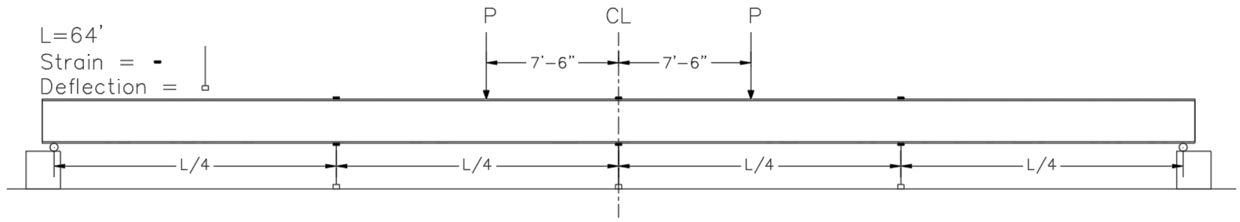


Figure 7. W30×173 non-composite bending test configuration

Non-composite testing was limited to inducing a midspan moment in the beam of approximately 50% of the yield moment (lateral torsional buckling controls) to reduce any chance of residual stress remaining in the beam prior to testing in a composite configuration.

The applied loads were recorded using two load cells installed at the point of loading. The beam was loaded up to 5.5 kips at each load location for the W24×68 beam and 16.7 kips at each load location for the W30×173 beam, which induced a moment of 70 kip-ft for the W24×68 beam and 420 kip-ft for the W30×173 beam at the midspans of the beams.

In this test, two categories of instrumentation (see Figure 8) were installed to collect data during the test: 350 ohm full Wheatstone bridge strain transducers and differential capacitance displacement transducers (DCDTs).

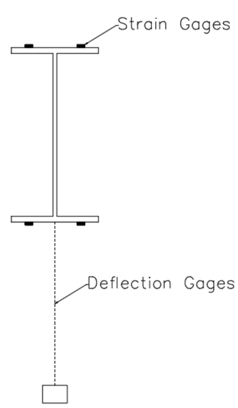


Figure 8. Non-composite instrumentation typical section

A total of 12 strain transducers, located at quarter spans and midspan, were placed on the top and bottom flanges to obtain strain data from the beam. Also, three DCDTs were placed vertically underneath the beam to record deflections under loading effects with those placed at quarter spans, midspan, and near two end supports.

While numerous deflection and strain gauges were used, and the data from them were reviewed for any anomalous behavior, the primary data of interest were those in the area of the maximum load effect, at center span. The following chapter discusses the results from the midspan gauges.

Images of the test setup are shown in Figure 9 through Figure 13.

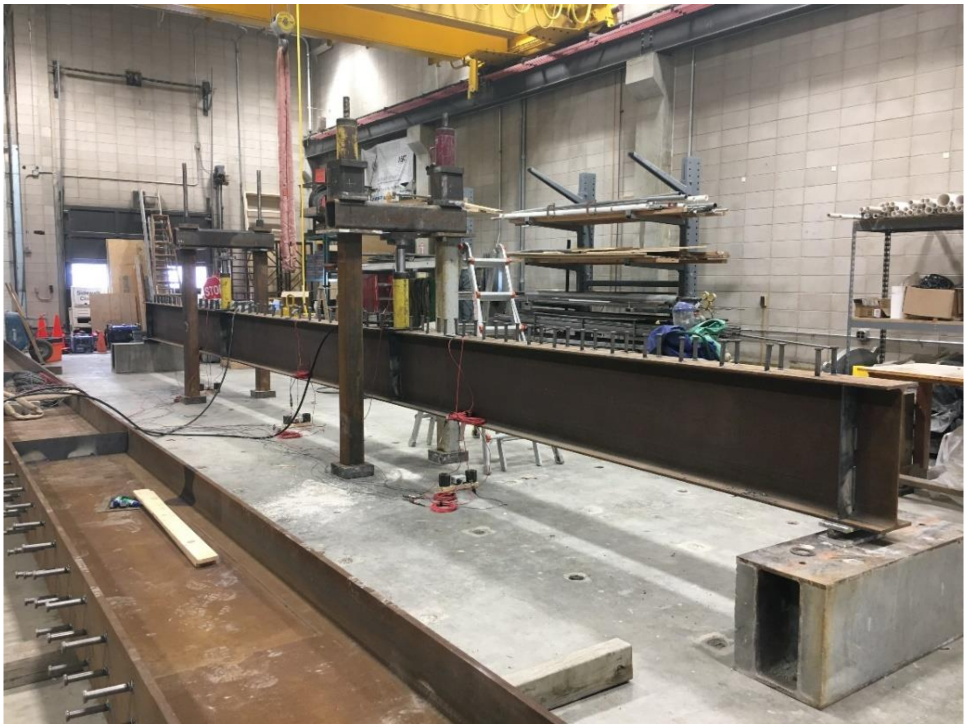


Figure 9. W24×68 non-composite load test

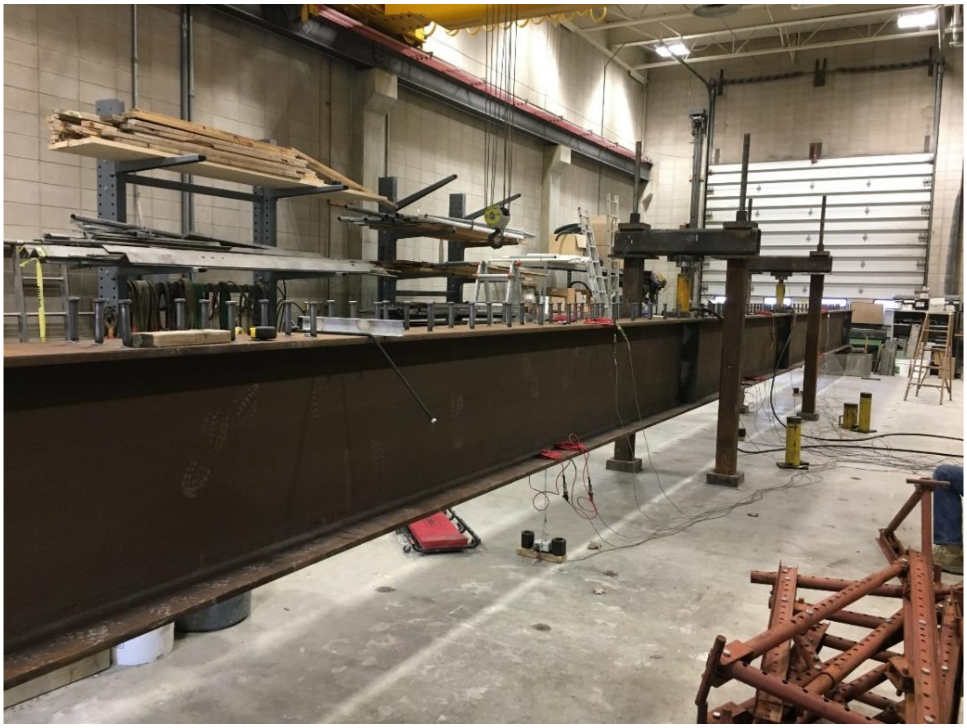


Figure 10. W30×173 non-composite load test

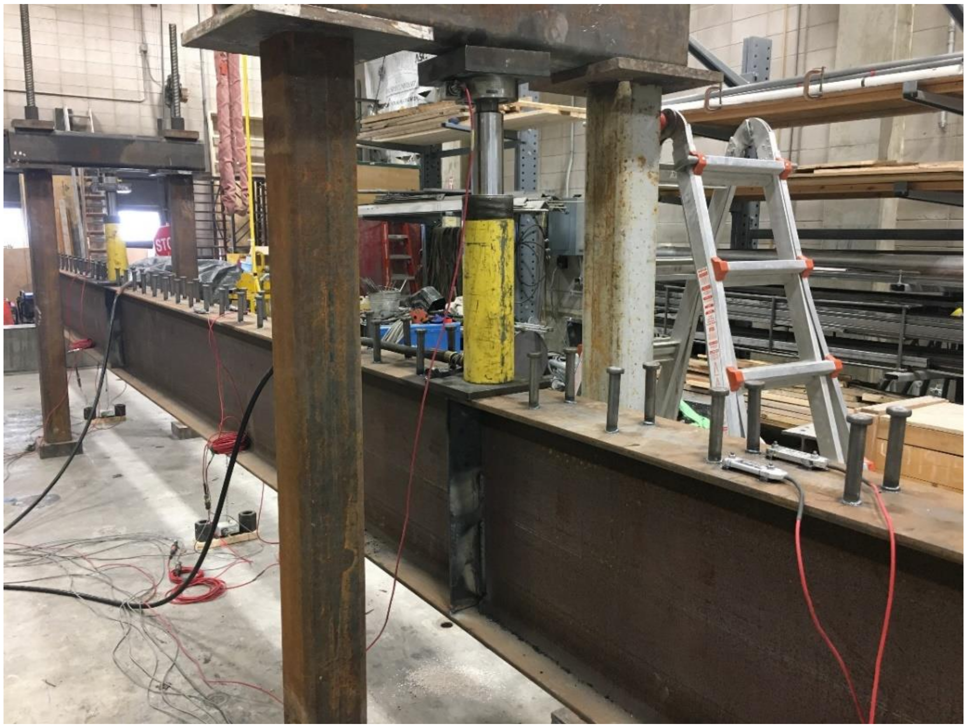


Figure 11. Load actuator

Figure 12. Strain gauges on non-composite beam

Figure 13. Deflection transducer

3.2 Composite Beam Load Tests

Similarly, the composite beam load tests were completed using a four-point bending loading scenario centered on the beam with 15 ft between point loads. The total clear span for the beams was the same as for the non-composite tests, 41 ft and 64 ft for the W24×68 and W30×173, respectively, as shown in Figure 14 and Figure 15.

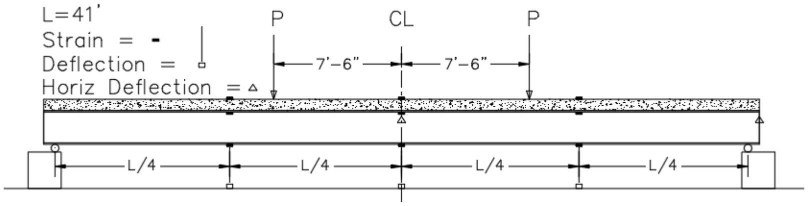


Figure 14. W24×68 composite bending test configuration

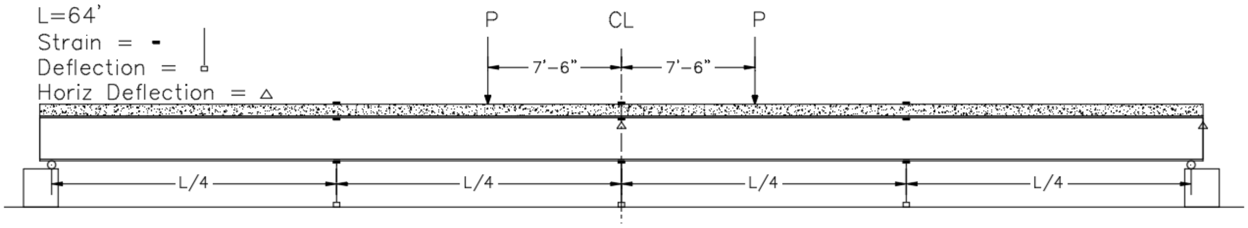


Figure 15. W30×173 composite bending test configuration

The beams were instrumented with top and bottom flange strain gauges and displacement transducers at quarter spans and midspan (see Figure 16).

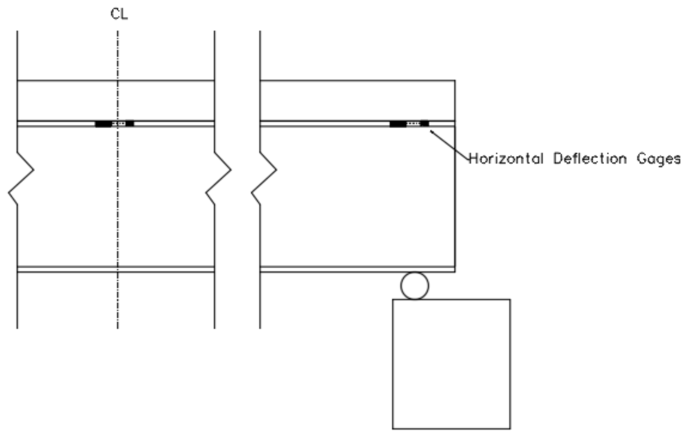


Figure 16. Two horizontal deflection gauges at end support and midspan

Strain gauges were also placed on the top of the deck at the same locations. Two additional deflection transducers were placed horizontally at midspan and one end to measure any slip between the deck and top flange.

The deck measured 8 in. in depth. The width measured 5 ft and 7 ft for the W24×68 and W30×173, respectively. The shear studs were 7/8 in. in diameter and 6 in. in depth. Top and bottom #4 steel reinforcement mats were placed in the deck with a spacing between 12 in. and 14 in. longitudinally and transversely, respectively. See Figure 17.

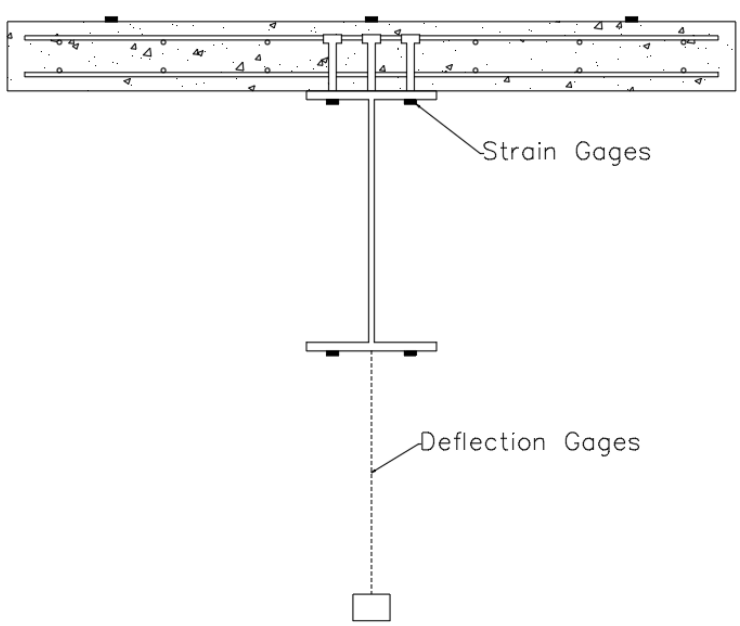


Figure 17. Composite beam instrumentation typical cross section

Images captured during construction of the deck are provided in Figure 18 through Figure 20.

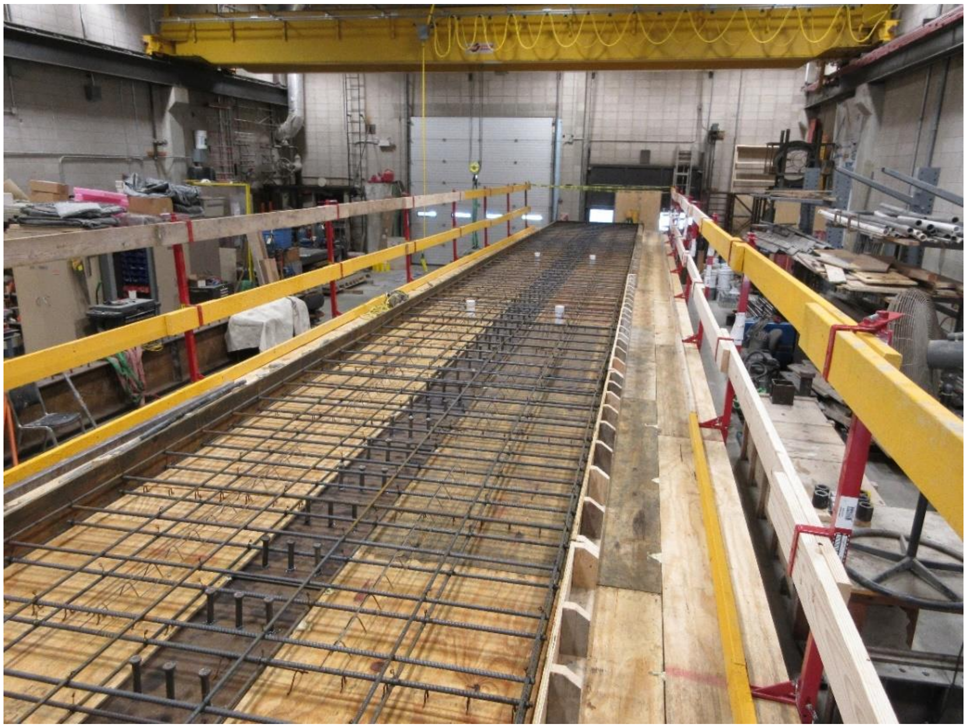


Figure 18. Composite deck reinforcement

Figure 19. Composite beam shear studs

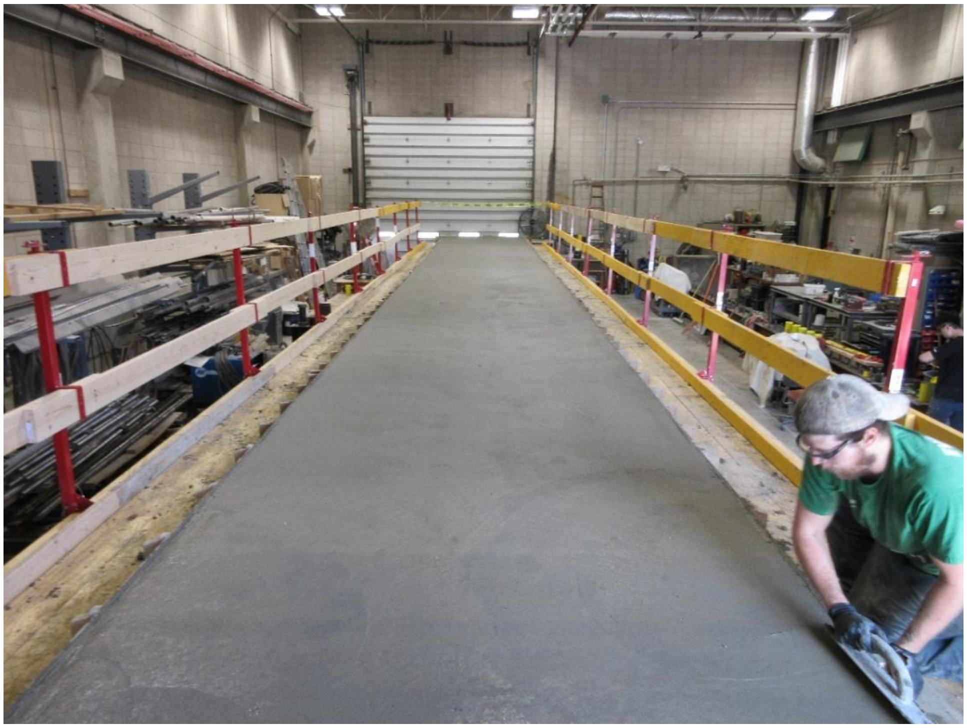


Figure 20. Composite deck concrete placement

After proper curing time for the deck concrete had elapsed, the specimens were tested under a four-point bending scenario to determine the composite flexural behavior of the Grade QST 65 steel-concrete composite section.

Initial load tests were completed to determine the composite behavior of the beams while maintaining their elastic properties. Once these tests were complete, the beams were loaded beyond the point of transition from elastic to plastic behavior in an effort to determine the ultimate flexural capacity of the steel-concrete composite beam.

Images captured during the load tests of the W24×68 and W30×173 beams are shown in Figure 21 through Figure 24.

Figure 21. W24×68 composite beam test

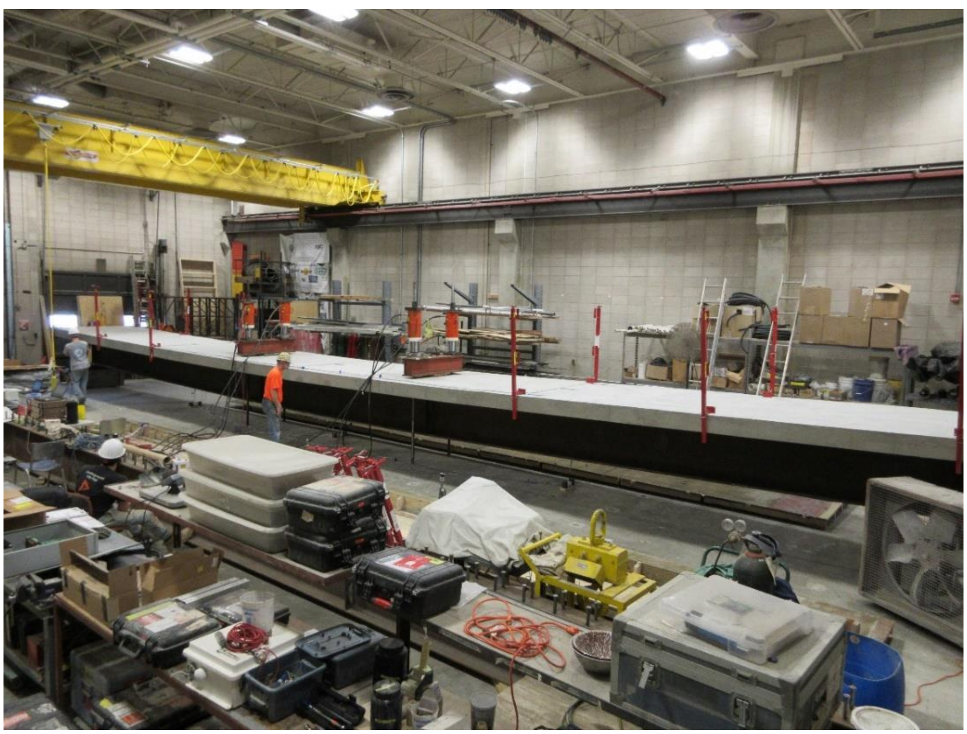


Figure 22. W30×173 composite beam test

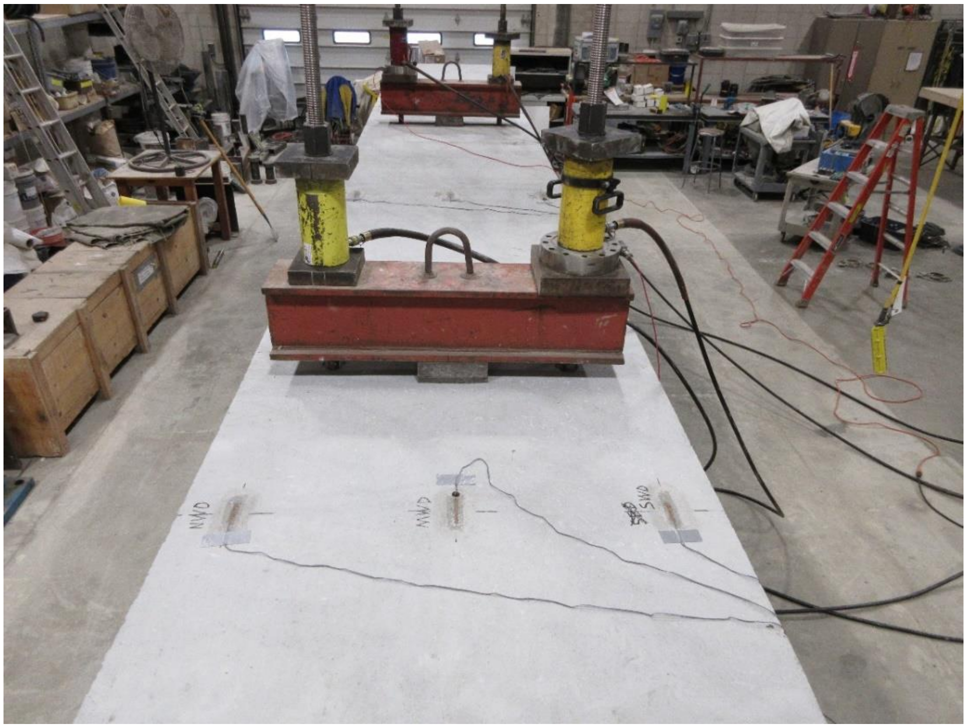


Figure 23. W24×68 composite beam load actuators

Figure 24. W30×173 composite beam load actuators

The applied loads were recorded using two load cells located beneath two of the hydraulic rams. For the initial composite beam tests, the beams were loaded up to 60 kips and 84 kips at each load location, which induced a moment of 780 kip-ft and 2,100 kip-ft at the midspan of the beam for the W24×68 and W30×173 beam, respectively.

After the initial tests were conducted and the setup was verified, the final tests were performed to evaluate the ultimate flexural capacity on the same steel-concrete composite girder, loading the beams past the yield point of the steel. The collected data were reduced and compared to the results from hand calculations per the AASHTO equations using designed and real material properties.

4 LABORATORY TEST RESULTS

4.1 Results Non-Composite Load Tests

Each Grade 65 QST beam was tested under four-point bending to verify the beam's pre-composite flexural behavior before construction of the concrete deck. For the W24×68 beam, it was loaded up to approximately 5.5 kips at each location, which induced a moment of 75 kip-ft at the midspan of the beam. For the W30×173 beam, it was loaded up to 16.7 kips, which induced a moment of 420 kip-ft.

The test results were compared to the results obtained from calculations performed by following elastic flexural theory, as shown in the following equations.

$$\delta = \frac{Pa}{24EI}(3L^2 - 4a^2)$$

where, δ is the deflection at midspan, P is the load at each location, L is the span, a is the distance between load location and end support, E is the modulus of elasticity, and I is the moment of inertia of the girder.

$$\sigma = \frac{M \times y}{I}$$

where, σ is the stress, M is the moment, and y is the distance to the neutral axis.

$$\sigma = E \times \varepsilon$$

where, σ is the stress, E is the modulus of elasticity, and ε is the measured strain.

The assumed modulus of elasticity for the calculations was 29,000 ksi, and the moment of inertia used for the W24×68 and W30×173 beams were 1,830 and 8,230 in^4, respectively.

Figure 25 and Figure 26 show the relationship between the measured load-displacement curve and that which was calculated for the W24×68 and W30×173 beams, respectively.

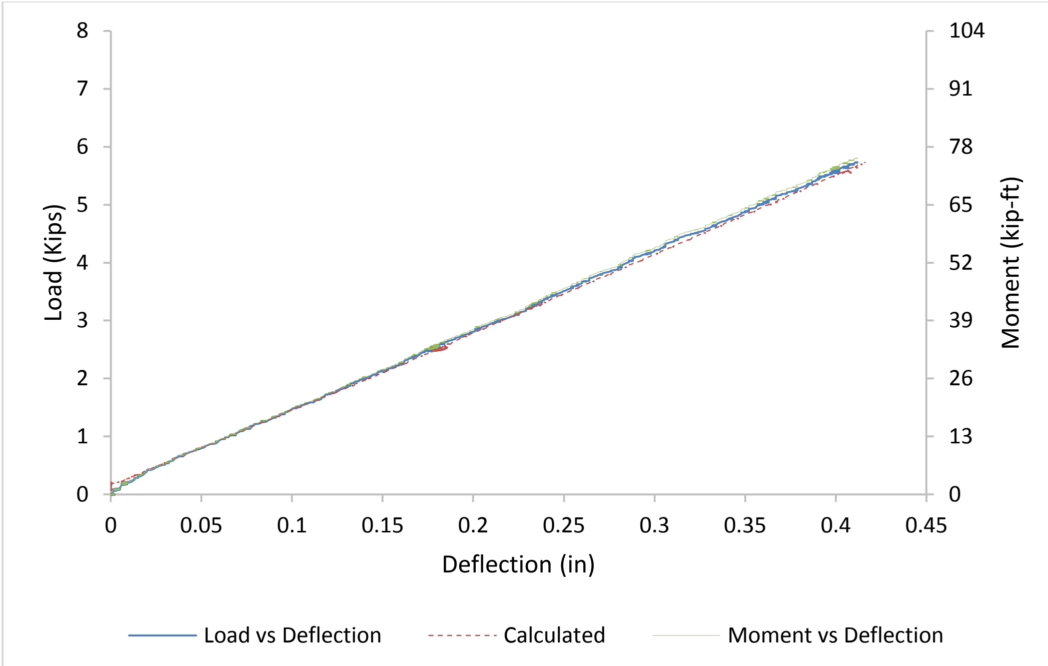


Figure 25. Load and moment vs. displacement at midspan for W24×68 non-composite bending tests

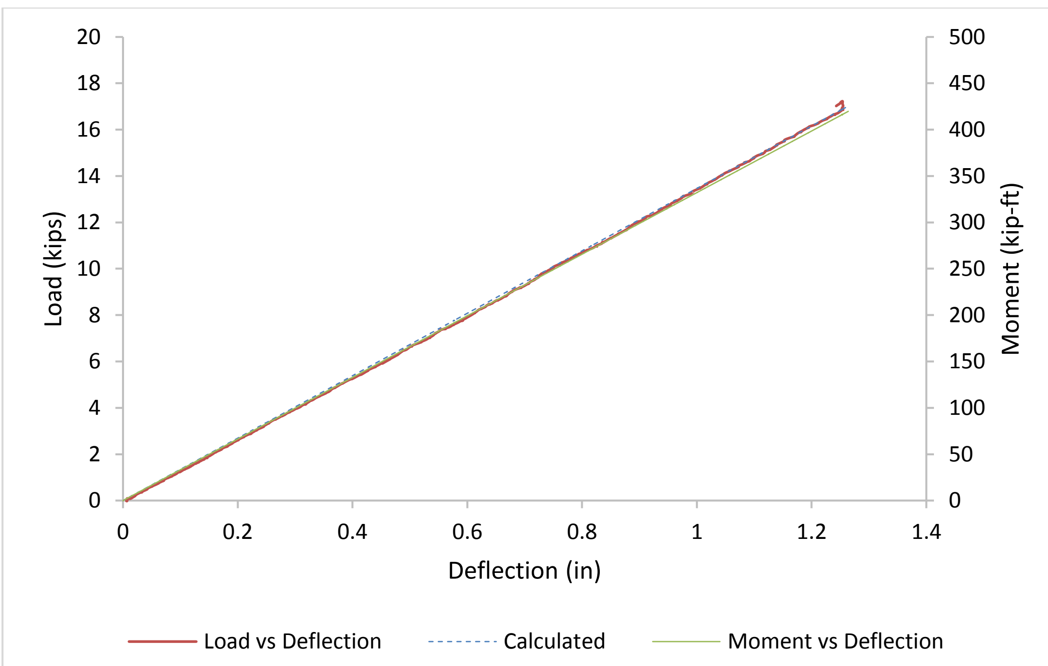


Figure 26. Load and moment vs. displacement at midspan for W30×173 non-composite bending tests

As shown in the plots, displacements measured during the tests were in good agreement with those obtained from the hand calculations.

Figure 27 and Figure 28 show the relationship between the calculated stress at the midspan bottom flange and the stresses calculated from the measured strain.

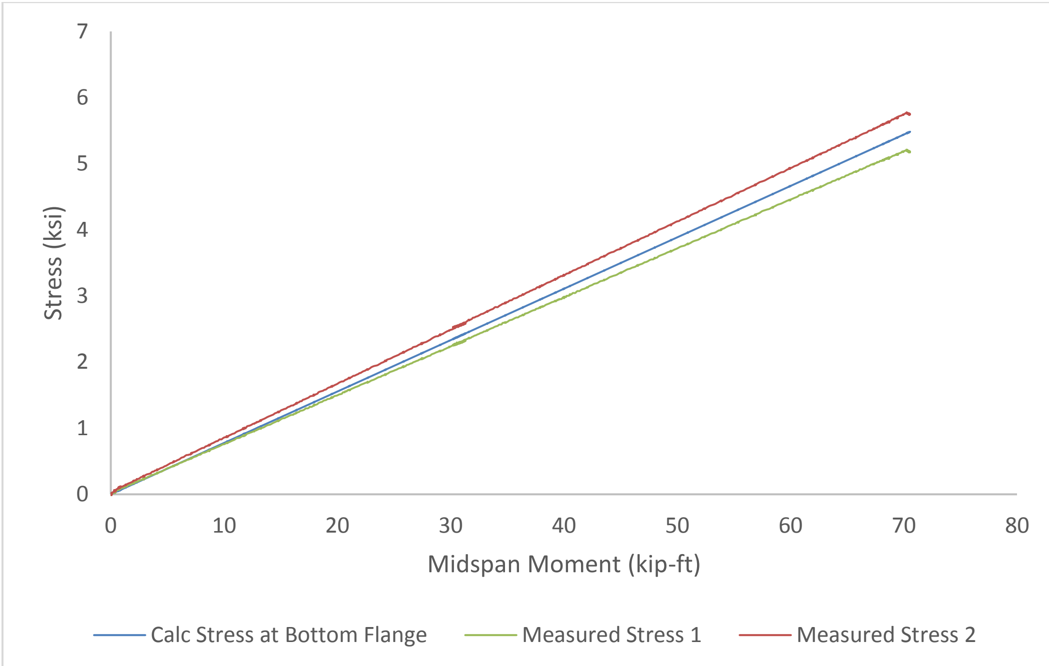


Figure 27 Stress vs. Midpsan Moment for Non-Composite W24×68

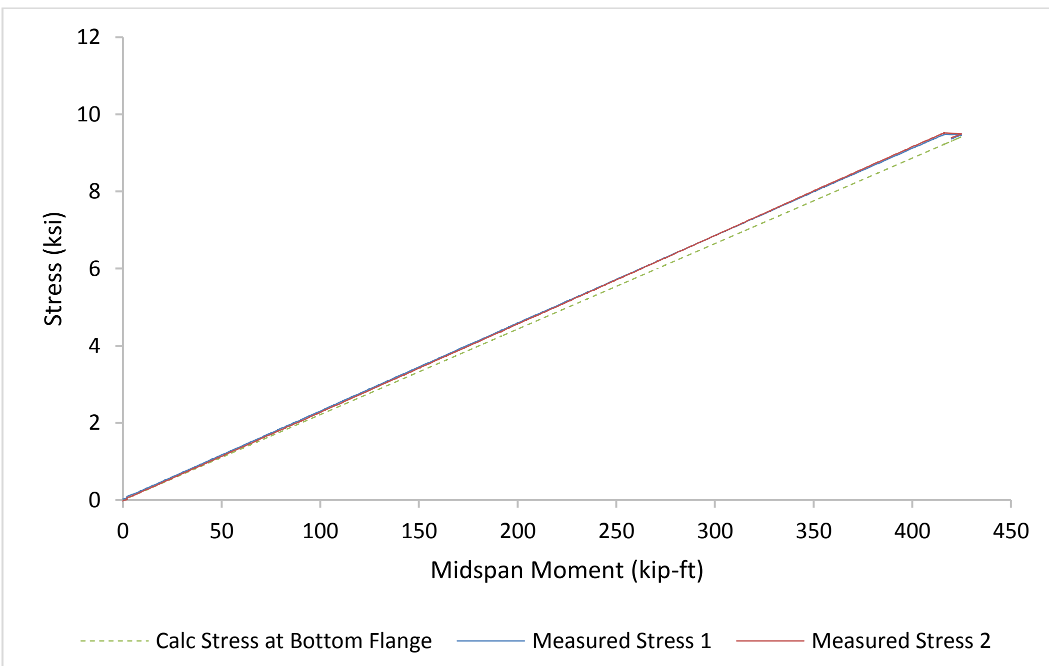


Figure 28. Stress vs. midpsan moment for non-composite W30×173

The slight deviation of the measured stresses above and below the calculated stress in Figure 27 is likely a function of slight rotation along the longitudinal axis of the beam.

4.2 Results of Composite Load Tests

For the composite W24×68 beam, Figure 29 and Figure 30 show the load and induced moment versus deflection and the stress versus strain curves, respectively.

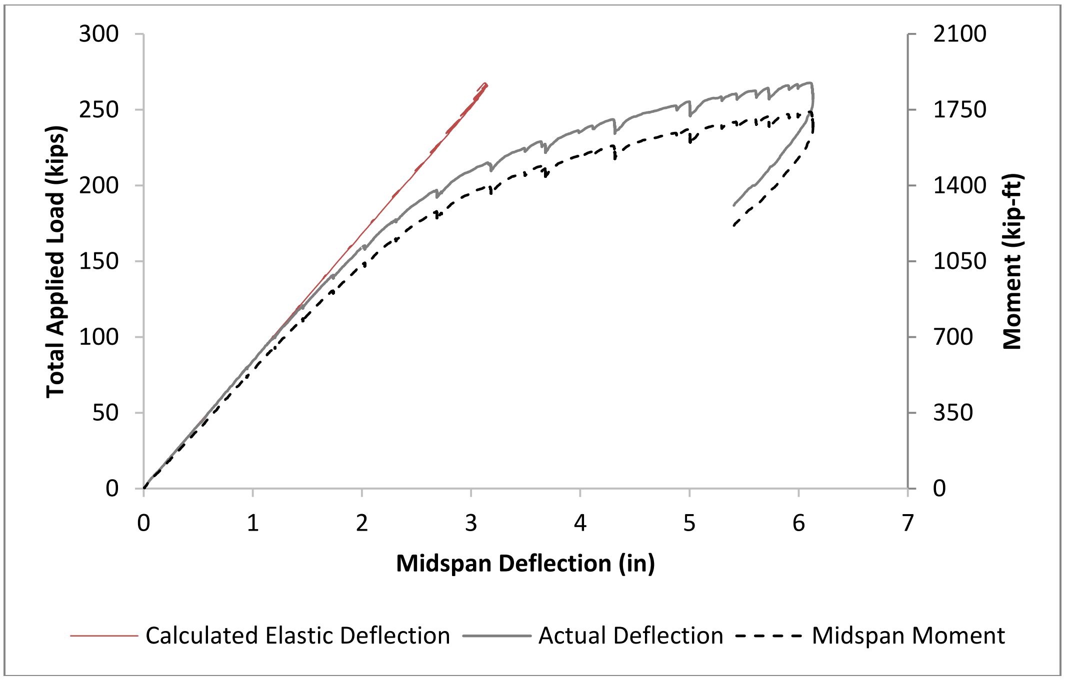


Figure 29. Midspan live load deflection for composite W24×68

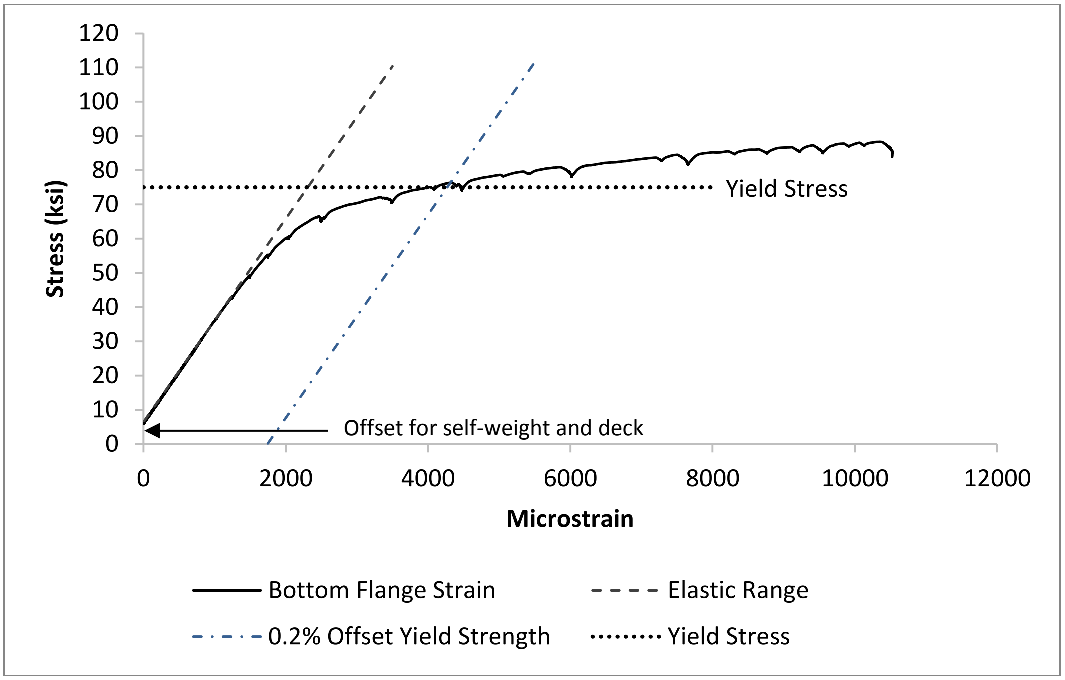


Figure 30. Midspan stress through inelastic range for bottom flange of composite W24×68

Included in the plot of Figure 29 is the calculated load versus deflection assuming elastic behavior of the beam, which compares well with the collected data until the transition to plastic behavior.

Figure 30 indicates the yield strength to be approximately 75 ksi as determined through the completed load tests. The initial stress was offset to account for the induced stress from the beam self-weight and the dead weight of the concrete in the non-composite state. For quenched and self-tempered low-alloy steels, the deviation from a constant-slope stress-strain relationship occurs gradually, which provides evidence of its ductility. The yield point is not discretely defined by a clear point of changed stress versus strain behavior as is typical with lower grade steels. Given the yield point is not a discretely defined, the yield strength is commonly defined at an offset of 0.2%.

Similarly, for the composite W30×173 beam, Figure 31 and Figure 32 show the load and induced moment versus deflection and the stress versus strain curves, respectively.

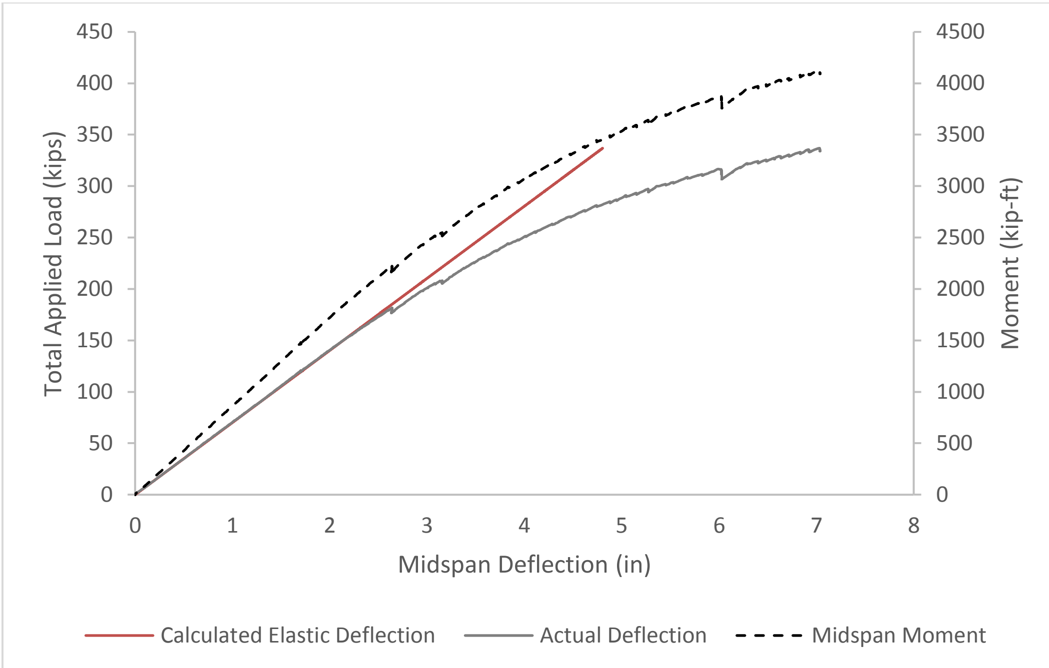


Figure 31. Midspan live load deflection for composite W30×173

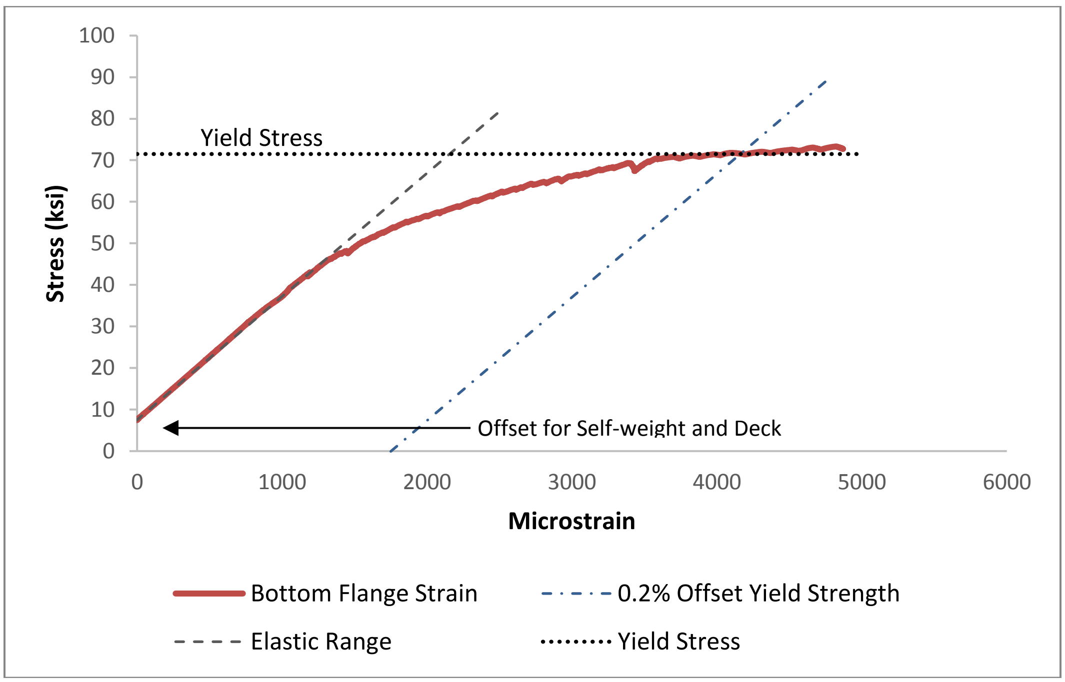


Figure 32. Midspan stress through inelastic range for bottom flange of composite W30×173

Included in the plot of Figure 31 is the calculated load versus deflection assuming elastic behavior of the beam, which compares well with the collected data until the transition to plastic behavior.

Figure 32 indicates the yield strength to be approximately 72 ksi as determined through the completed load tests. The initial stress was also offset to account for the induced stress from the beam self-weight and the dead weight of the concrete in the non-composite state. The yield strength was defined at an offset of 0.2% as is typical for quenched and tempered low-alloy steels.

In both cases of composite testing, the yield strength was determined to meet and exceed the minimum yield strength requirement of 65 ksi for the Grade QST 65 steel.

5 TENSILE AND FATIGUE TESTS

5.1 Tensile Test

To determine the mechanical properties of Grade QST 65 steel, such as yield strength, ultimate tensile strength, and elongation at fracture, a tensile test was conducted on a coupon (Figure 33) under a steadily increasing load by using a material testing system from MTS Systems Corporation.

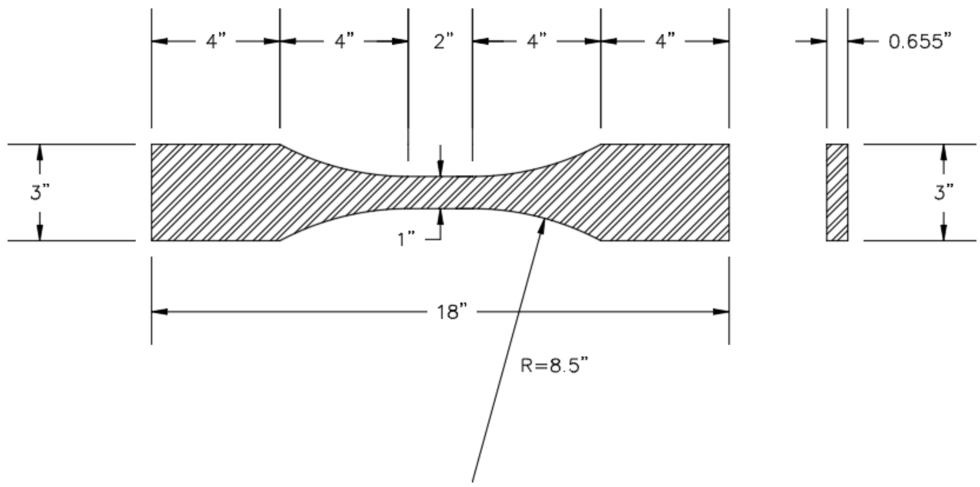


Figure 33. Coupon geometry

The geometry of the coupons was designed by following the standard test method according to ASTM E8 (ASTM 2016). Water-jet cutting was utilized to produce the tensile and fatigue coupons. The steel was taken from the W30×173 beam web within the elastic region after the ultimate bending test. Figure 34 and Figure 35 show the equipment used to prepare the coupons for the tensile tests.

Figure 34. Water-jet controls

Figure 35. Fatigue sample water-jet cutting

The MTS loading machine and its associated system were used for tensile testing. The 0.2% offset yield strength was defined as the yield strength for the Grade QST 65 steel coupon specimens given alloy steels do not exhibit a well-defined yield point. Table 2 shows the yield strength and modulus of elasticity of a single specimen loaded in tension to failure.

Table 2. Summary of Grade QST 65 coupon tensile test

Sample	Modulus of elasticity (ksi)	Yield strength (ksi)	Ultimate strength (ksi)	Elongation at break in 4 in. (%)
8	28,200	69.0	86.0	17.5
ASTM Grade QST 65	29,000	65	80	18.0

The yield strength and modulus of elasticity values were determined to be 69 ksi and 28,200 ksi, respectively. The obtained results were compared to the minimum required mechanical properties of structural steels used for bridges, which are also shown in Table 2, as documented in the ASTM A913/A913M specification.

Figure 36 shows stress versus strain for the Grade QST 65 coupon tensile test.

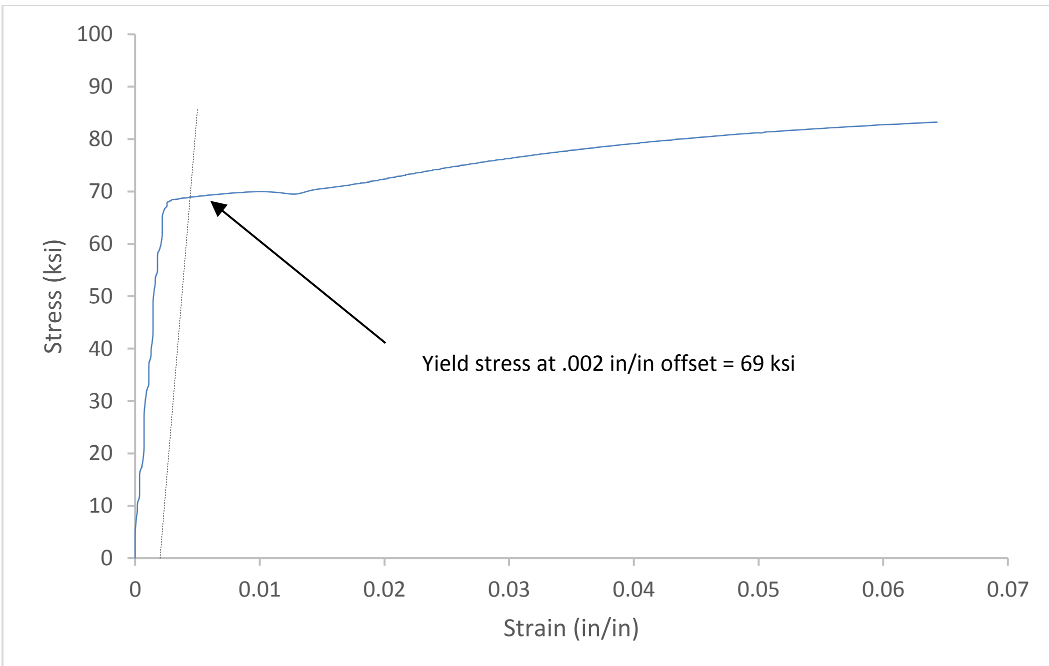


Figure 36. Stress vs. strain for Grade QST 65 coupon tensile test

5.2 Fatigue Tests

To investigate the fatigue performance of Grade QST 65 steel, following the tensile test, several fatigue tests of varying peak stress levels ensued using specimens of the same geometry previously shown in Figure 33. Each specimen was subjected to cyclic tension loading under the stress-controlled protocol at room temperature. The specimens were repeatedly loaded and unloaded in a range between no load and a pre-defined percentage of the maximum tensile stress until failure. The fatigue test was performed on an MTS hydraulic machine, as shown in Figure 37, with a frequency of 5 Hz.

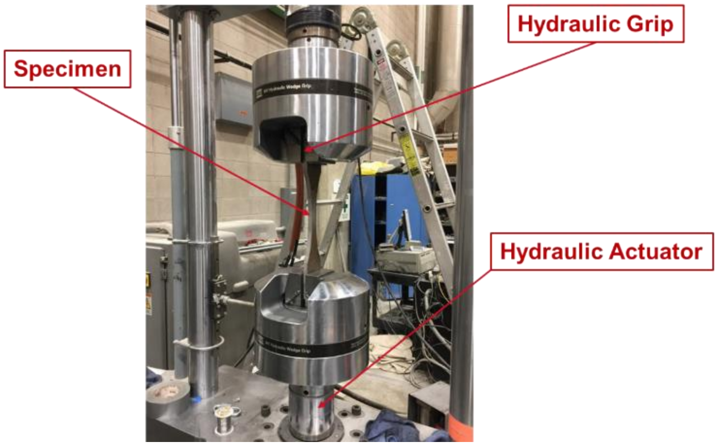


Figure 37. Fatigue load test equipment setup

Fatigue tests were terminated when a specimen fractured or the number of fatigue cycles reached 2,000,000 cycles. This number was decided based on results obtained from other performed steel fatigue tests. Table 3 shows the number of cycles to fracture for each of the Grade 65 QST fatigue specimens.

Table 3. Number of cycles to fracture for Grade QST 65 specimens

Coupon ID	Frequency (Hz)	Max stress* (ksi)	Thickness (in.)	Width (in.)	Area (in.^{2})	Load cycles
7	5	55.20	0.655	1.00	0.655	125,662
6	5	51.75	0.655	1.00	0.655	181,716
5	5	48.30	0.655	1.00	0.655	279,819
4	5	44.85	0.655	1.00	0.655	336,839
3	5	41.40	0.655	1.00	0.655	389,892
2	5	37.95	0.655	1.00	0.655	862,762
1	5	34.50	0.655	1.00	0.655	2,000,000

* Maximum tensile stress, and load range begins at 0 kip

Using the stress magnitude, σ_A, versus fatigue life, N_f, the fatigue behavior curve may be expressed mathematically as the following equation.

$$\sigma_A = a(N_f)^B$$

The constants *a* and ^{B} were obtained from a regression analysis of the tested stress- and fatigue-life data. In this study, the fatigue limit was defined as the stress amplitude level below which no fatigue failure takes place (i.e., the fatigue cycle of 2,000,000). The fatigue limit for Grade 65 QST steel subjected to high-cycle fatigue tests is shown in the S-N plot, or the relationship between cyclic stress amplitude and the number of cycles to failure, in Figure 38.

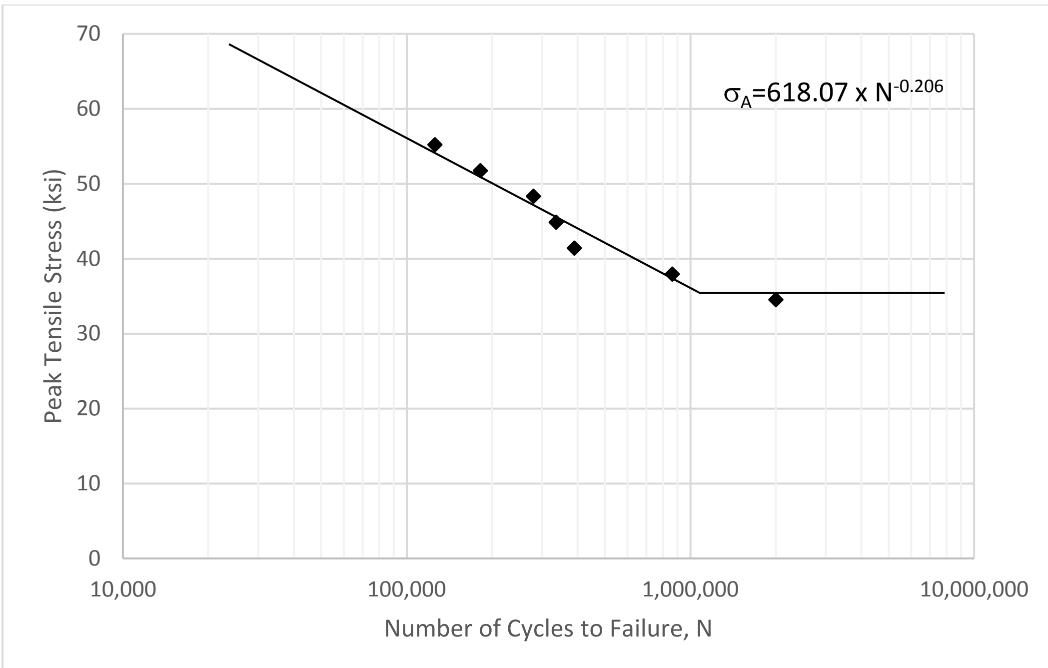


Figure 38. S-N curve for Grade QST 65 steel

The black diamonds in the graph indicate the number of cycles recorded prior to fracture at the respective tensile stress magnitude shown on the vertical axis. The fatigue limit for Grade 65 QST steel was found to be between 34.50 ksi (largest stress magnitude with no failures) and 37.95 ksi (smallest stress amplitude with failures). Therefore, it was concluded that Grade 65 QST steel could provide adequate fatigue resistance according to current fatigue design provisions.

Figure 39 shows the fracture locations for each specimen upon completion of the fatigue testing.

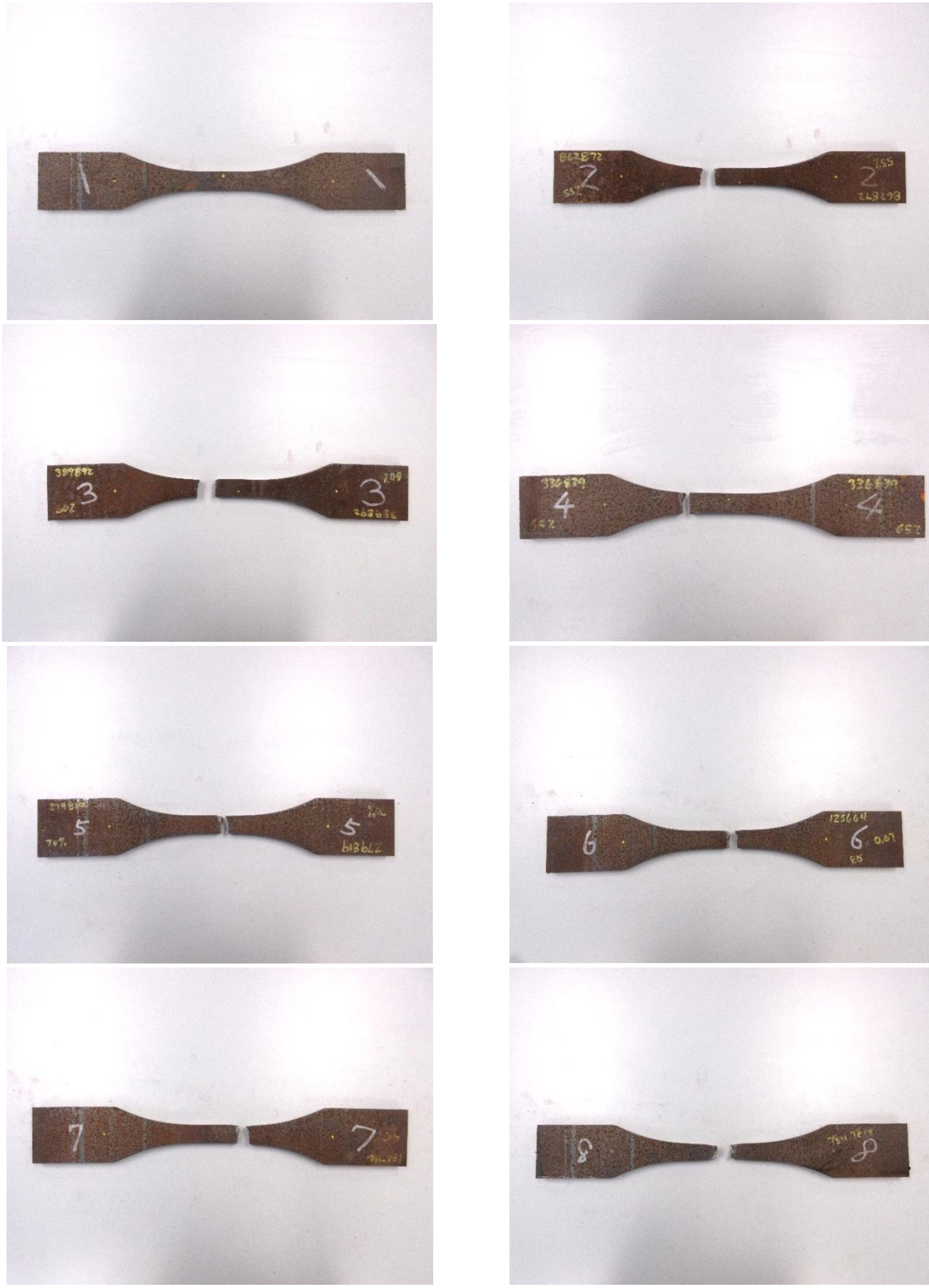


Figure 39. Fracture locations for fatigue samples

6 BRIDGE CONSTRUCTION AND TESTING

6.1 Bridge Construction

The condition and functionality of the former bridge over Sand Creek in Buchanan County necessitated its replacement. The bridge was shorter in length and didn't allow proper drainage of the surrounding agricultural fields. In extreme rain events, the bridge inhibited the hydraulic flow resulting in flooding of nearby land. The replacement bridge was lengthened to accommodate additional flow.

In 2019, the single-span bridge on 310th Street, 1 mile west of County Road (CR) W-35 near the intersection with Overland Avenue, south of Quasqueton, Iowa was replaced with the single-span concrete and steel composite beam bridge shown in Figure 40.

Figure 40. Buchanan County Sand Creek Bridge

6.1.1 Steel Girder Size and Cost Comparison

The original design called for W24×84 A992 Grade 50 beams, 41 ft long. A revised design using A709 Grade QST 65 steel allowed for a reduction in section size to W24×68 due to the increased yield strength. As a secondary advantage, 3 in. of additional vertical channel clearance was gained. Due to the lighter section size and near-equivalent steel price for each grade, a reduction in steel cost was realized.

The girder plan is shown in Figure 41.

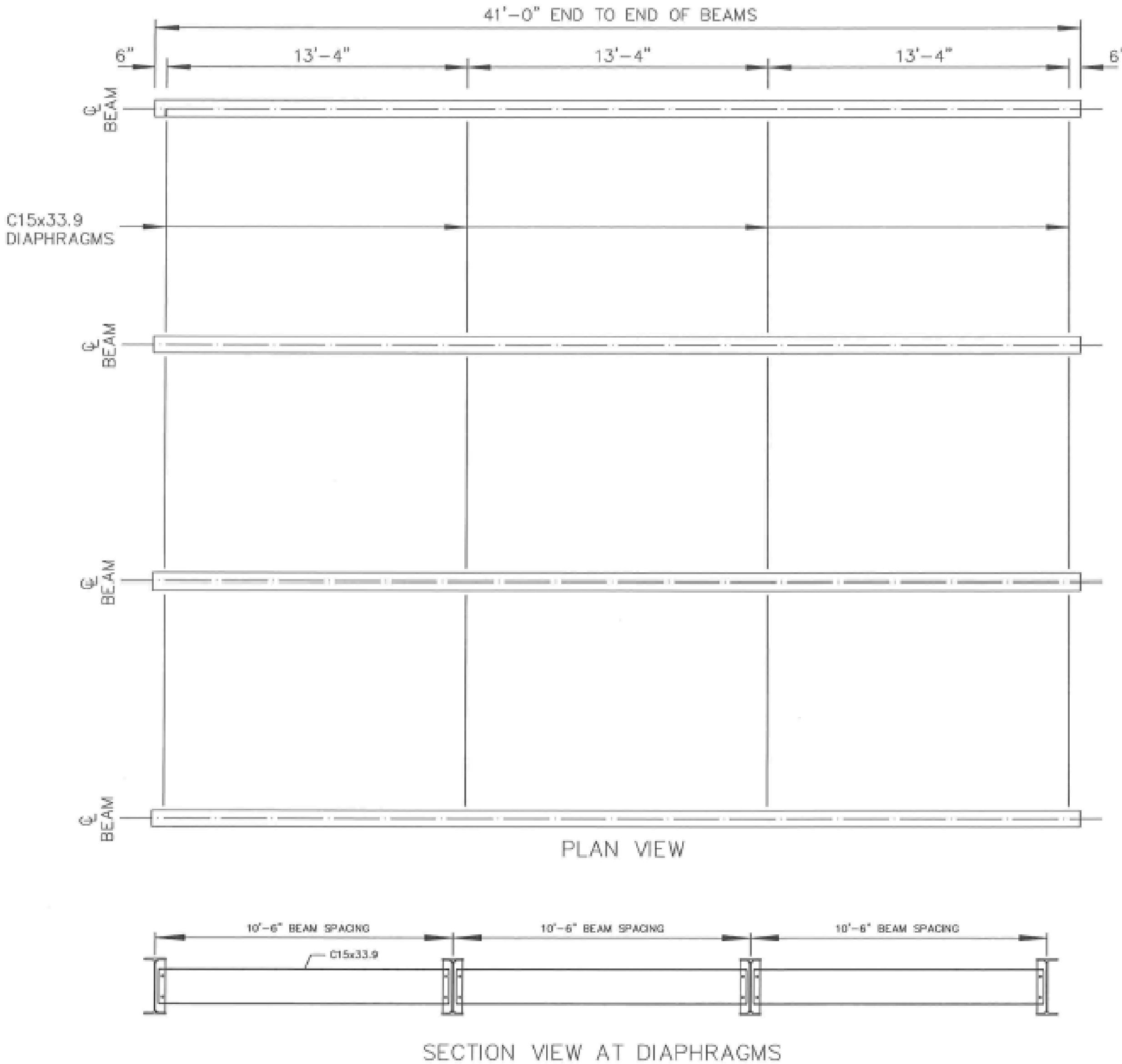


Figure 41. Sand Creek Bridge girder plan

The steel cost for this bridge was briefly discussed in a previous chapter. To reiterate, the bridge was originally designed using W24×84 A992 Grade 50 beams. At the time of construction, four beams 42 ft long and weighing 84 plf costing $45.50/hundred lbs would result in a material cost of $6,400. The modified design, which used A709 Grade QST 65 steel beams, allowed for a reduction in beam weight to a W24×68 due to the increased strength. The total steel cost for these beams was about $5,200, which resulted in a 20% material cost savings.

6.2 Live Load Tests

To assess the performance of the bridge over time, the bridge was subjected to several live load tests.

Three total live load field tests were completed about 1, 2, and 3 years after construction completion. Strain data were collected while a loaded truck of known weight and dimensions was driven across the bridge.

The vehicle made several passes on the bridge on designated load paths at a walking pace resulting in a quasi-static condition. The data were compared to identify if any changes in structural behavior had occurred over that period of time.

In June of 2020, the first of the three live load tests was completed. Subsequent live load tests were completed to compare the bridge behavior over time. The single tandem-axle, fully loaded, dump truck shown in Figure 42 was used for the load vehicle.

Figure 42. Test 1 load test vehicle

The gross vehicle weight was 56,320 lbs with the weight distributed to each axle as shown in Figure 43.

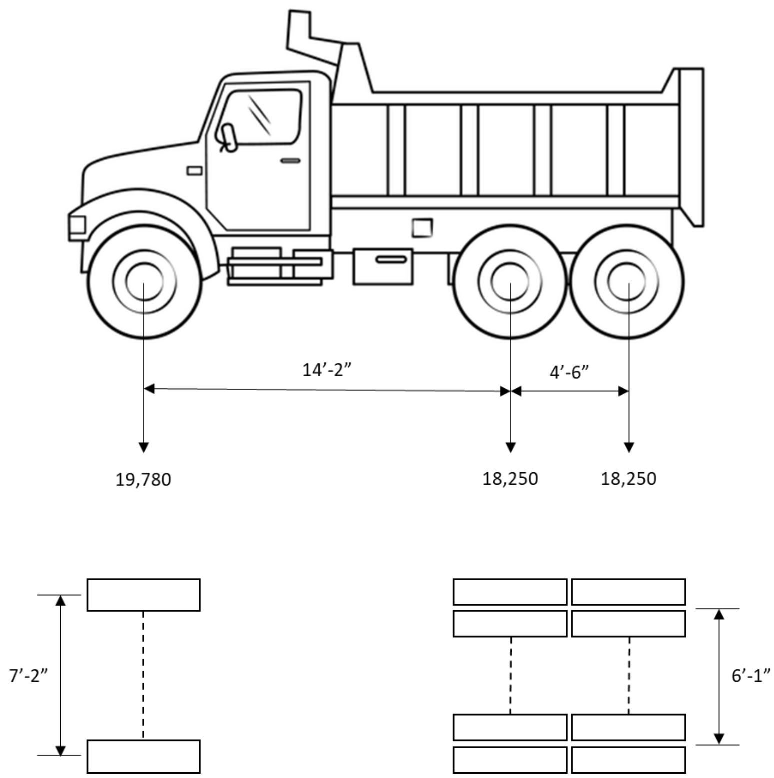


Figure 43. Test 1 load test vehicle axle weights and dimensions

In August of 2021, the second of the three live load tests was completed. The single tandem-axle, fully loaded, dump truck shown in Figure 44 was used for the load vehicle.

Figure 44. Test 2 load test vehicle

The gross vehicle weight was 50,540 lbs with the weight distributed to each axle as shown in Figure 45.

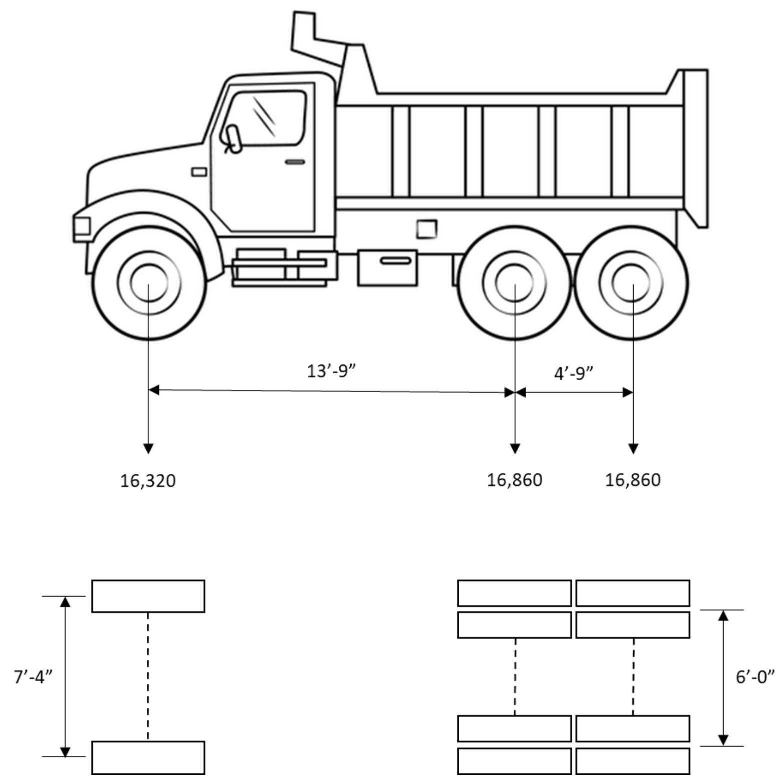


Figure 45. Test 2 load vehicle weights and dimensions

In May of 2022, the third of the three live load tests was completed. The single tandem-axle, fully loaded, dump truck shown in Figure 46 was used for the load vehicle.

Figure 46. Test 3 load test vehicle

The gross vehicle weight was 50,860 lbs, with the weight distributed to each axle as shown in Figure 47.

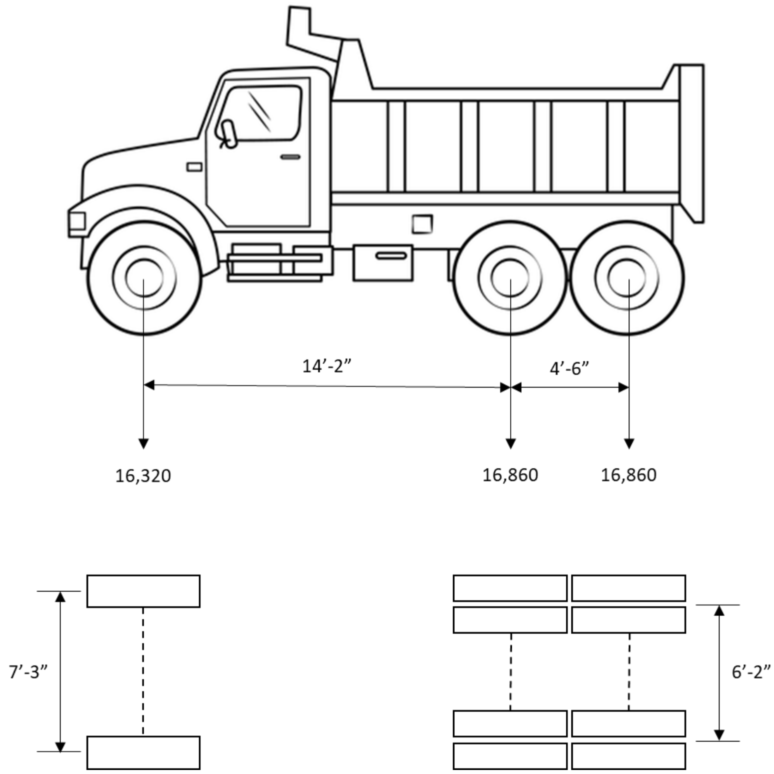


Figure 47. Test 3 load vehicle weights and dimensions

As shown in Figure 48, the loaded dump truck traveled from east to west along five unique load paths.

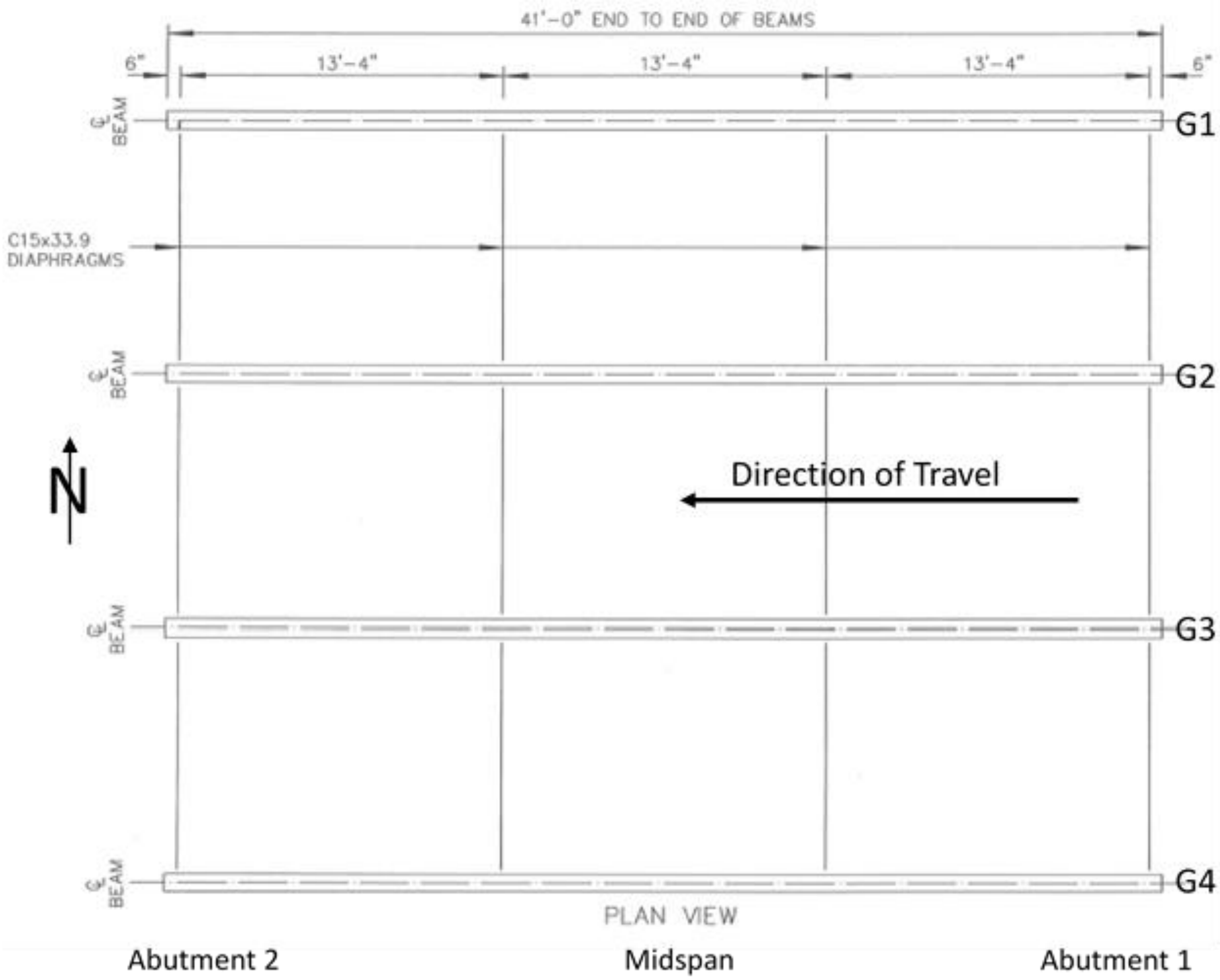


Figure 48. Test 1 load test plan view

The first load case placed the driver side wheels 2 ft from the edge of deck. The second load case placed the passenger side wheels 2 ft from the centerline of the deck. The third load case placed the centerline of the truck on the centerline of the bridge. Load Cases 4 and 5 were mirror images of Load Cases 2 and 1, respectively.

The load paths (load cases) were marked on the bridge (see Figure 49), and strain data were collected during each pass.

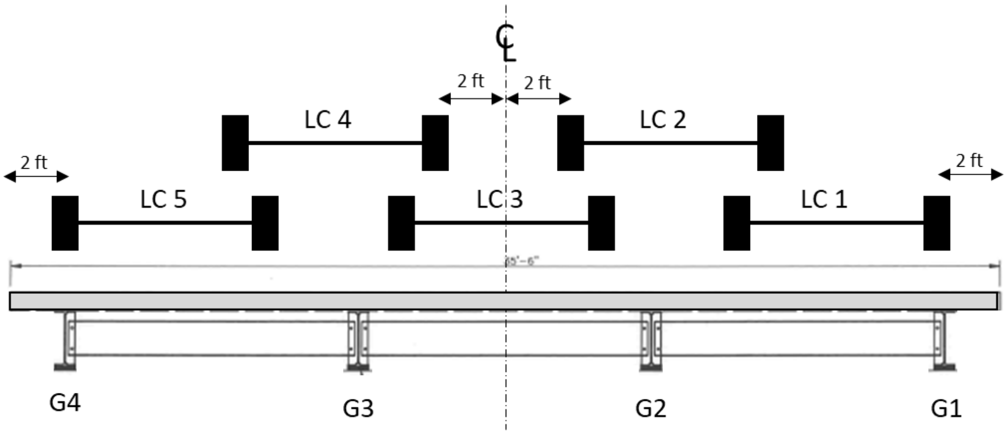


Figure 49. Test 1 load cases

Strain data were collected at the top and bottom flange of each girder at midspan and near each abutment as shown in the instrumentation plan in Figure 50 and in the images in Figure 51 and Figure 52, respectively.

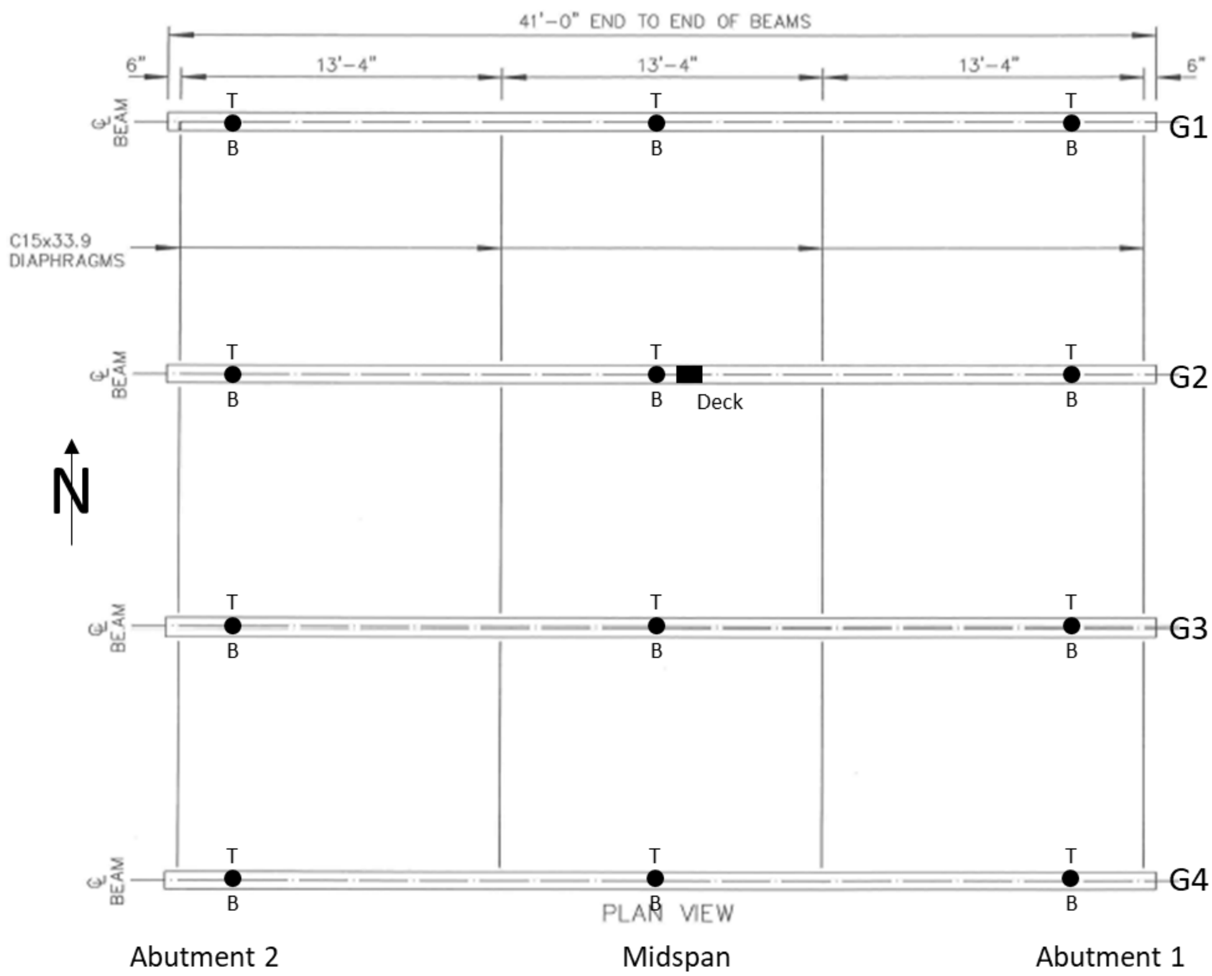


Figure 50. Strain gauge placement

Figure 51. Strain gauges at midspan

Figure 52. Strain gauges at abutments

Additionally, the top of deck strain values were collected at the midspan of one interior girder to assess the composite behavior of the girder and deck, as shown in Figure 53 and Figure 54.

Figure 53. Deck strain gauges

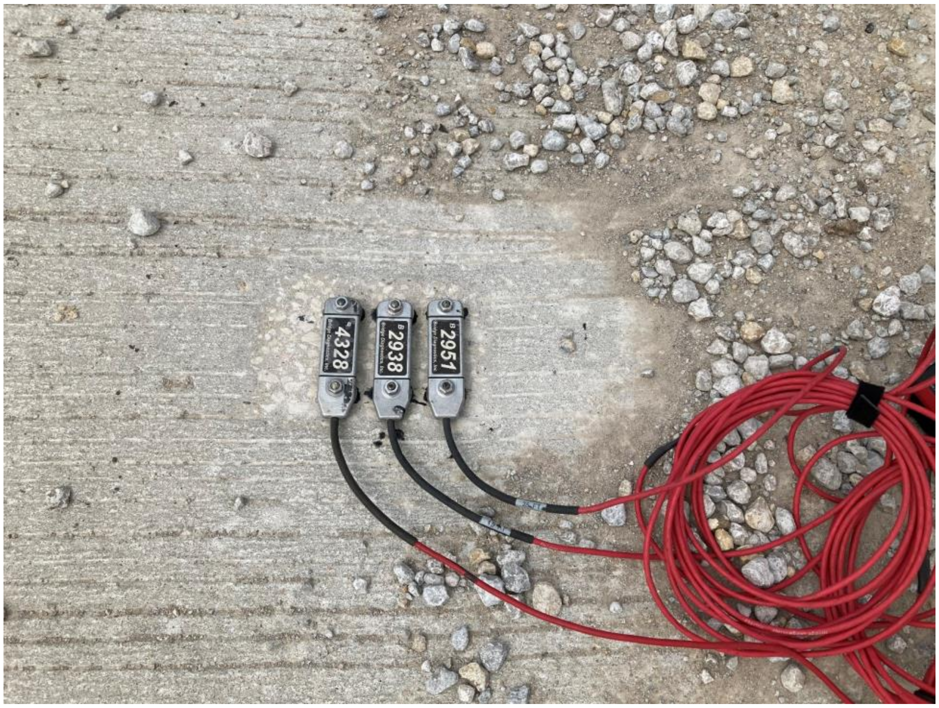


Figure 54. Close-up of deck strain gauges

6.3 Load Test Results and Comparison

Each test produced a strain-time history for each gauge, which indicated the measured strain relative to the load vehicle longitudinal position. Typical strain signatures observed at each abutment and midspan are presented in Figure 55 through Figure 57.

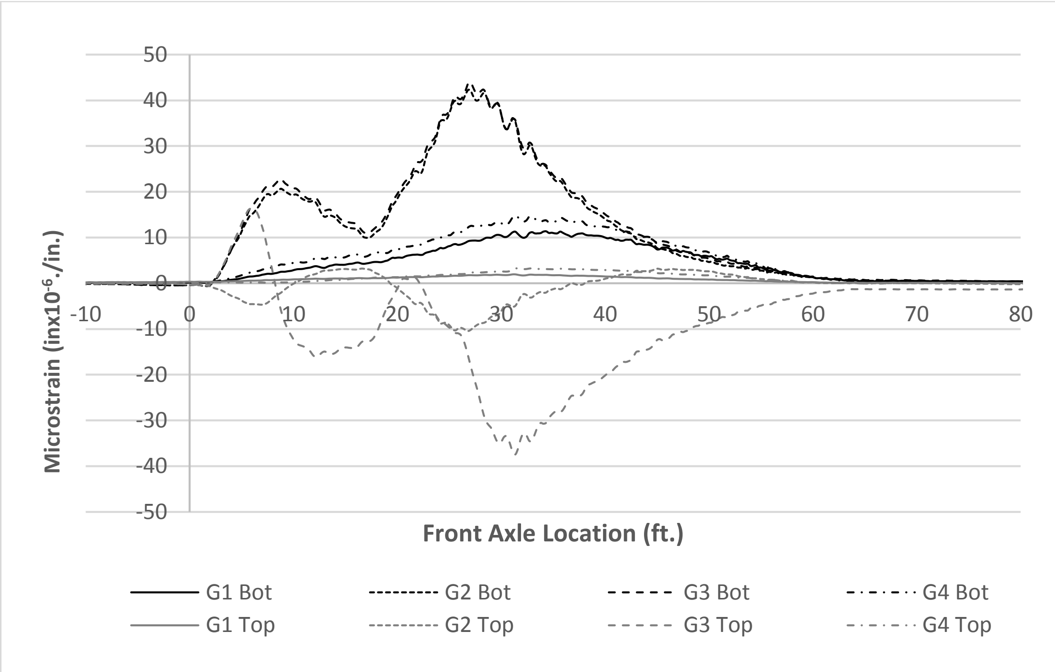


Figure 55. Typical strain history at Abutment 1

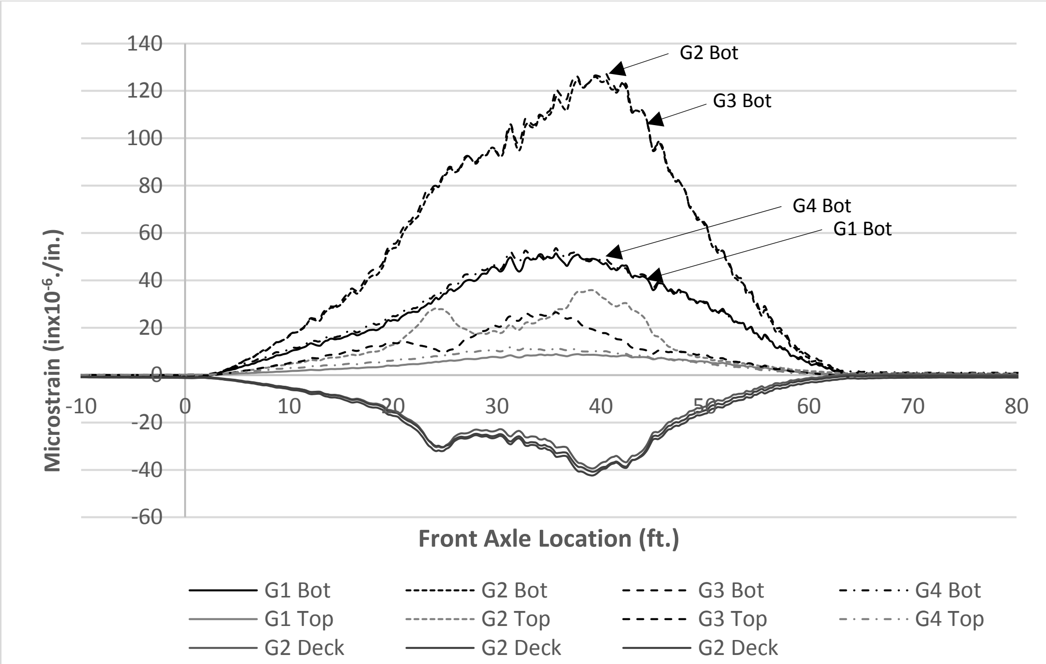


Figure 56. Typical strain history at midspan

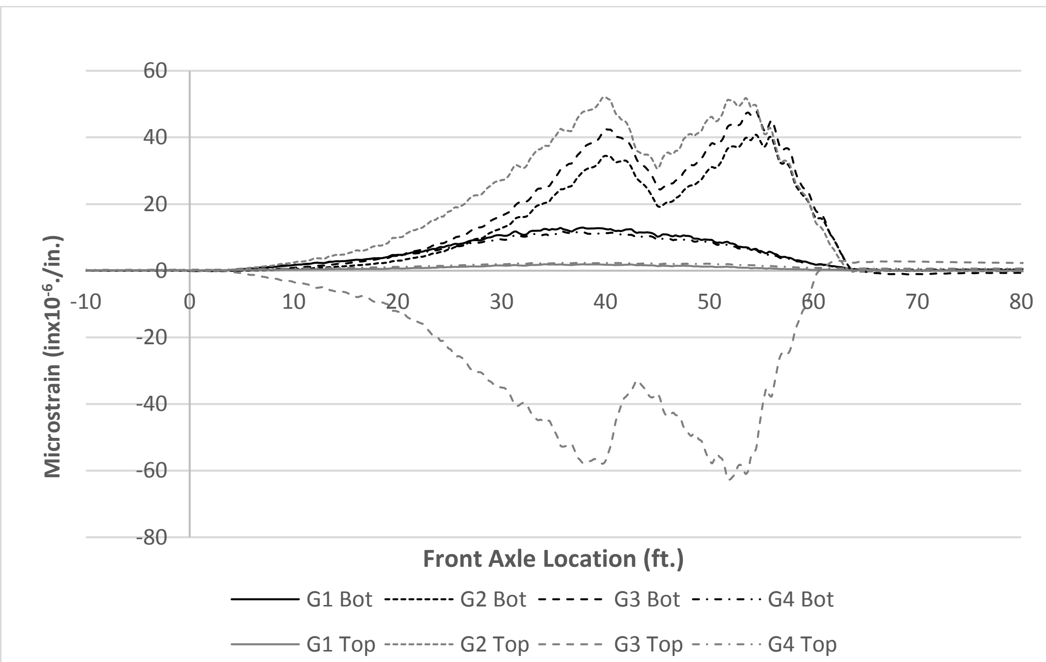


Figure 57. Typical strain history at Abutment 2

Interestingly, despite the placement of shear studs on the top flange of the beams, the results indicate non-composite behavior in Girders 2 and 3 at the abutment locations as seen in Figure 55 and Figure 57. This behavior was observed in each of the three completed tests. Beyond the possibility of missing shear studs, it is unknown what would otherwise be causing this behavior.

For these plots, Load Case 3 (the truck centered on the bridge) is shown. Positive results are tensile strain, and negative results are compression strain.

The data collected during each test were compared to detect any noteworthy changes in structural behavior from year to year. The strain data were normalized to 50,000 lb gross vehicle weight (GVW) to account for the slight weight differences between vehicles (i.e., 56,320 lbs, 50,040 lbs, and 50,860 lbs).

For brevity, only the locations where the maximum strain values were observed are presented in this report. Figure 58 through Figure 62 present the strain values at the bottoms of the girders at midspan for each test and each load case (T1-G1 = Test 1 for Girder 1, T1-G2 = Test 1 for Girder 2, etc.).

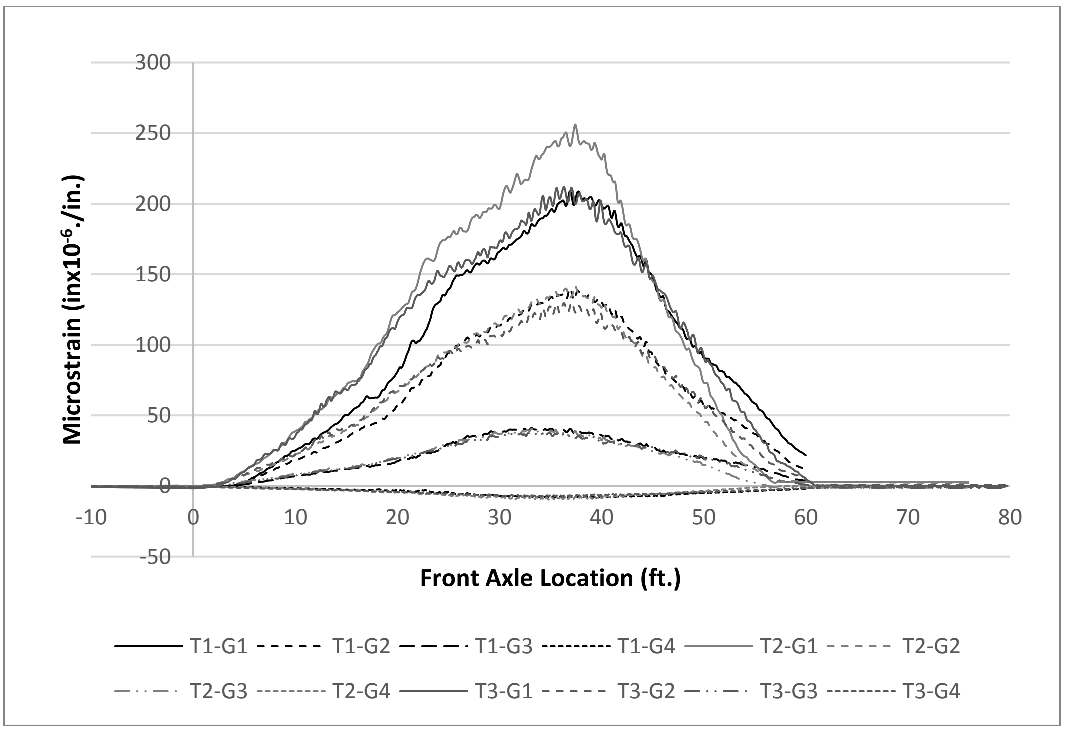


Figure 58. Comparison of strain for Load Case 1

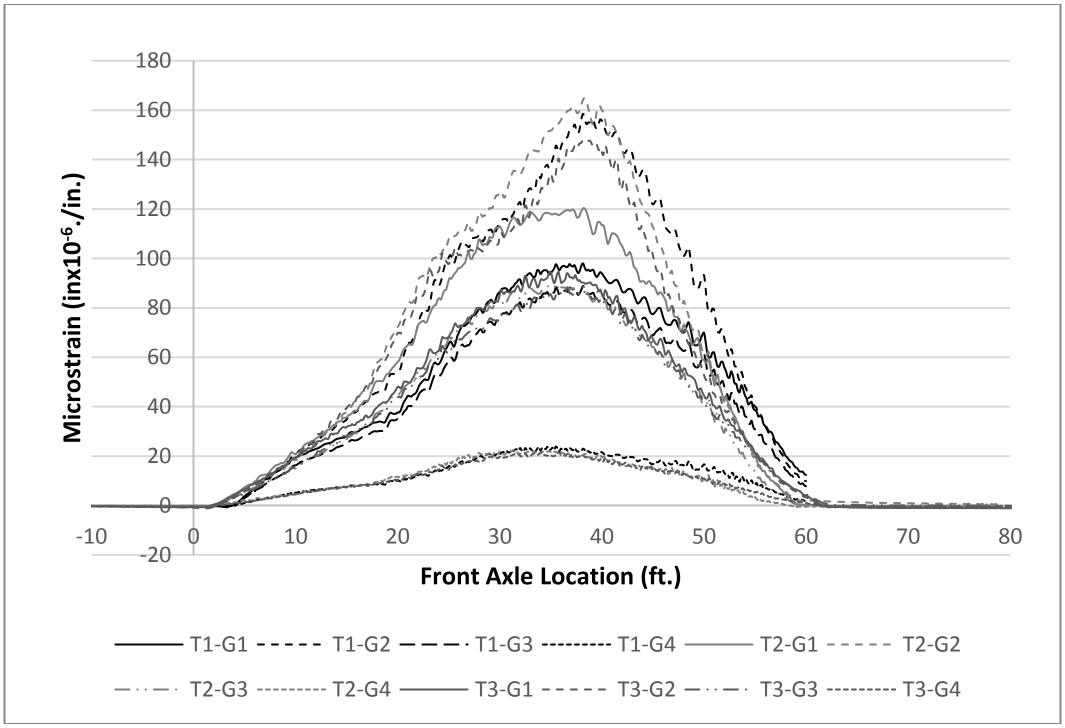


Figure 59. Comparison of strain for Load Case 2

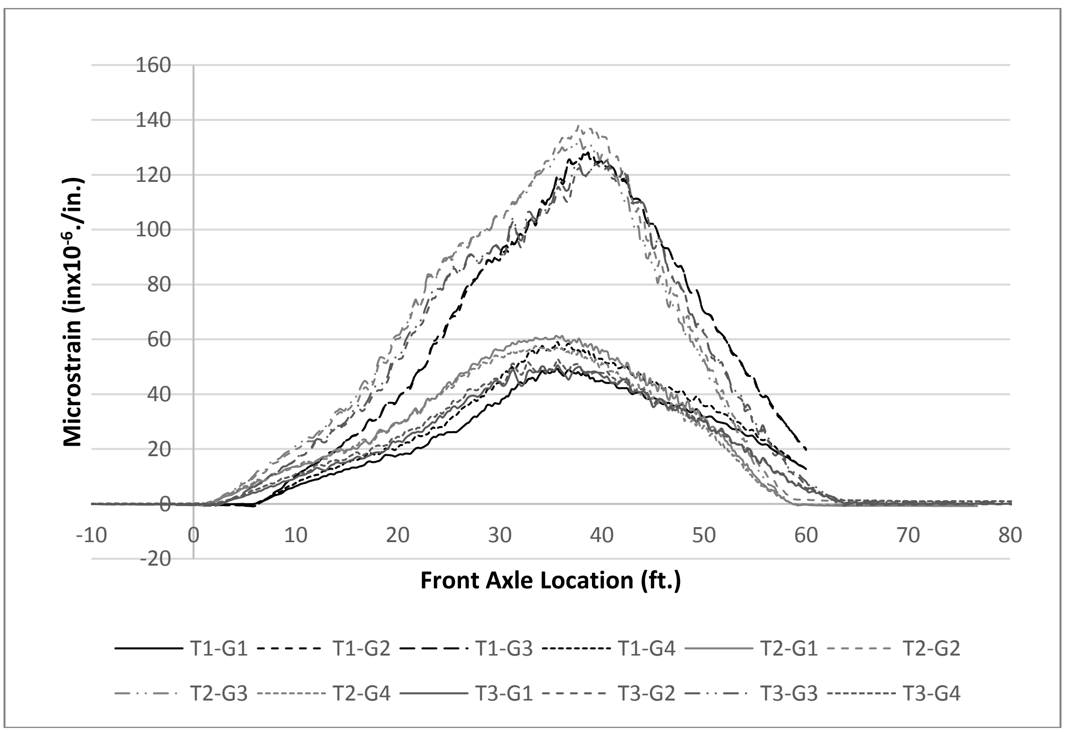


Figure 60. Comparison of strain for Load Case 3

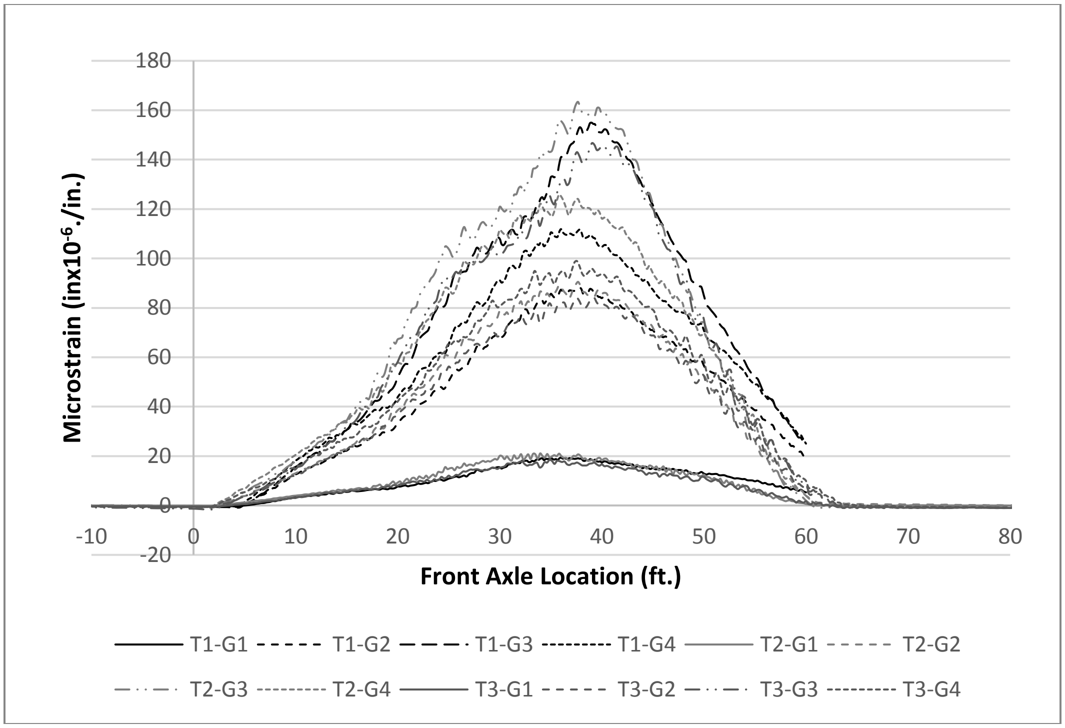


Figure 61. Comparison of strain for Load Case 4

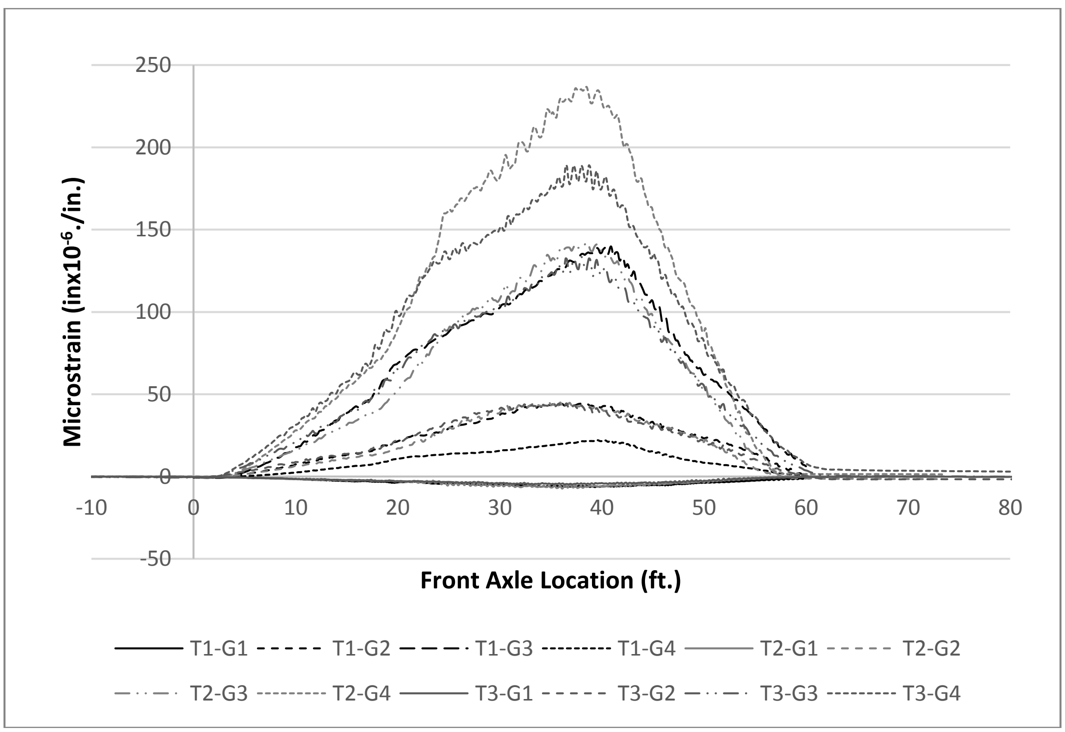


Figure 62. Comparison of strain for Load Case 5

Comparing the results for each test, in almost every case, the strain values were similar in magnitude. Variations in strain magnitudes may be attributed to minor deviations in the truck path or load distribution among the rear tandem axles. Although every effort to maintain consistency between truck passes was made, the truck may deviate in one direction or the other by several inches.

The rear tandem axles are weighed as one unit and the weight is assumed equal between the axles for purposes of testing. However, the weight may favor one axle over the other. Regardless, the comparative strain data did not indicate a deviation in overall structural behavior from year to year.

Using the strain data results and an assumed modulus of elasticity of 29,000 ksi, steel stress levels could be calculated in the girder flanges. The plots shown in Figure 63 through Figure 67 show the comparisons of maximum tensile stresses at the bottom of each girder at midspan for each load test where the maximum overall stress occurred.

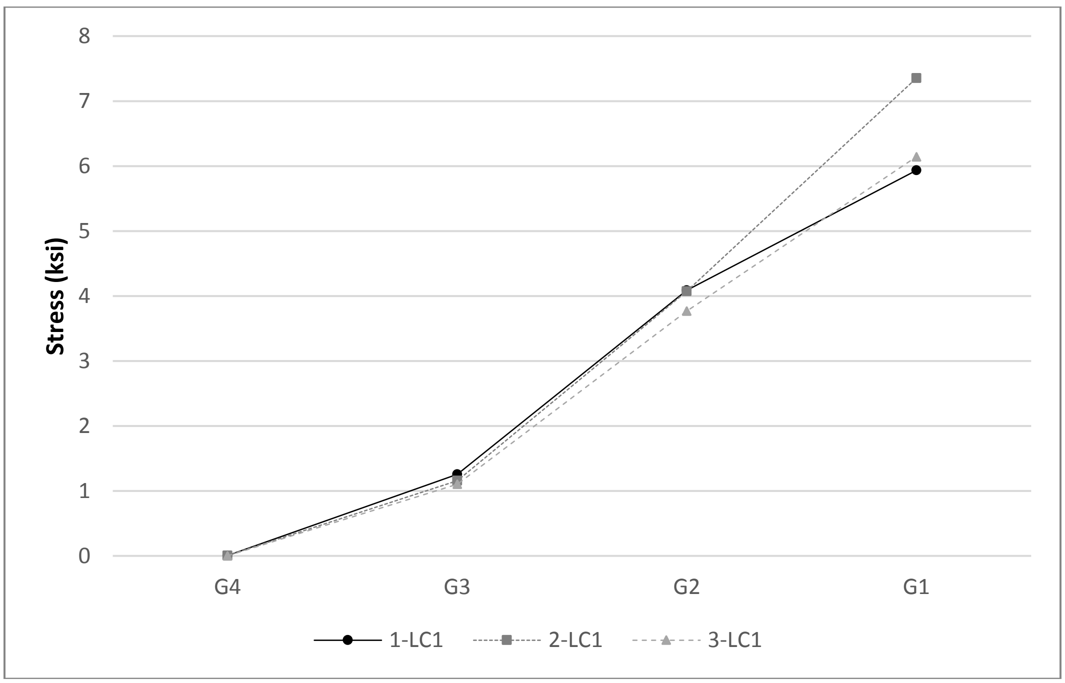


Figure 63. Maximum stress comparison for Load Case 1

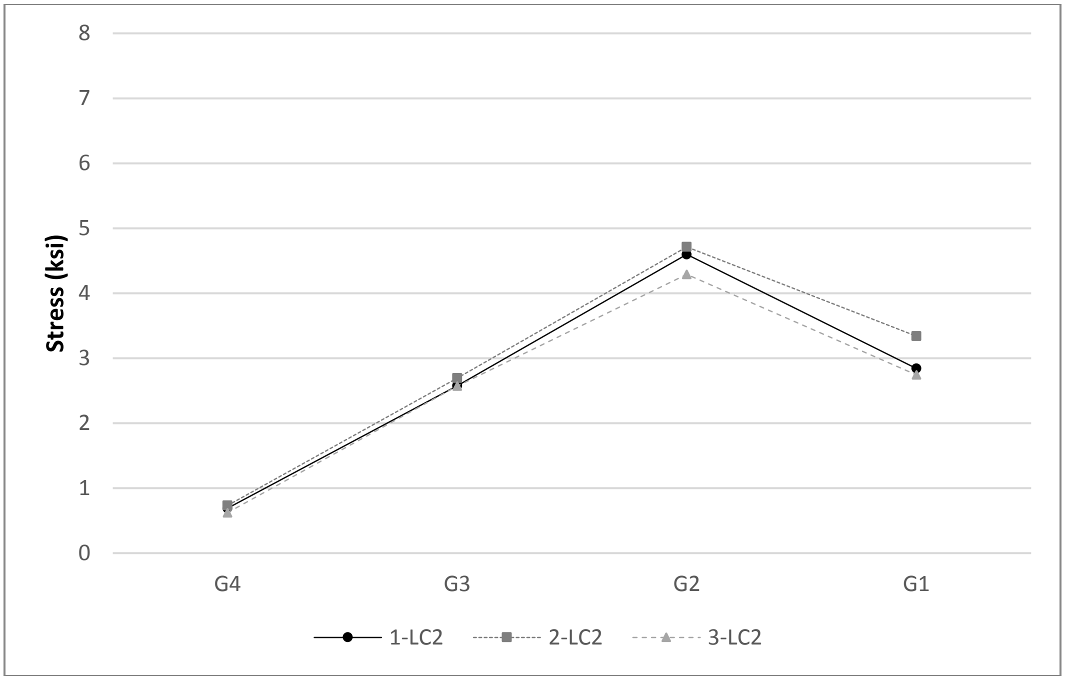


Figure 64. Maximum stress comparison for Load Case 2

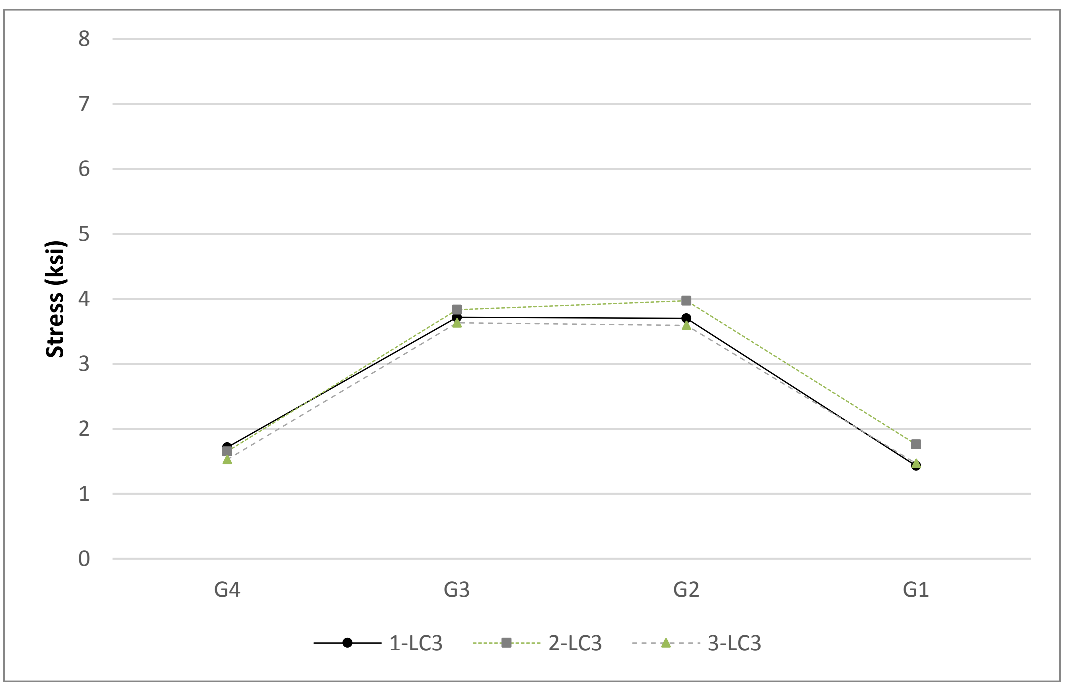


Figure 65. Maximum stress comparison for Load Case 3

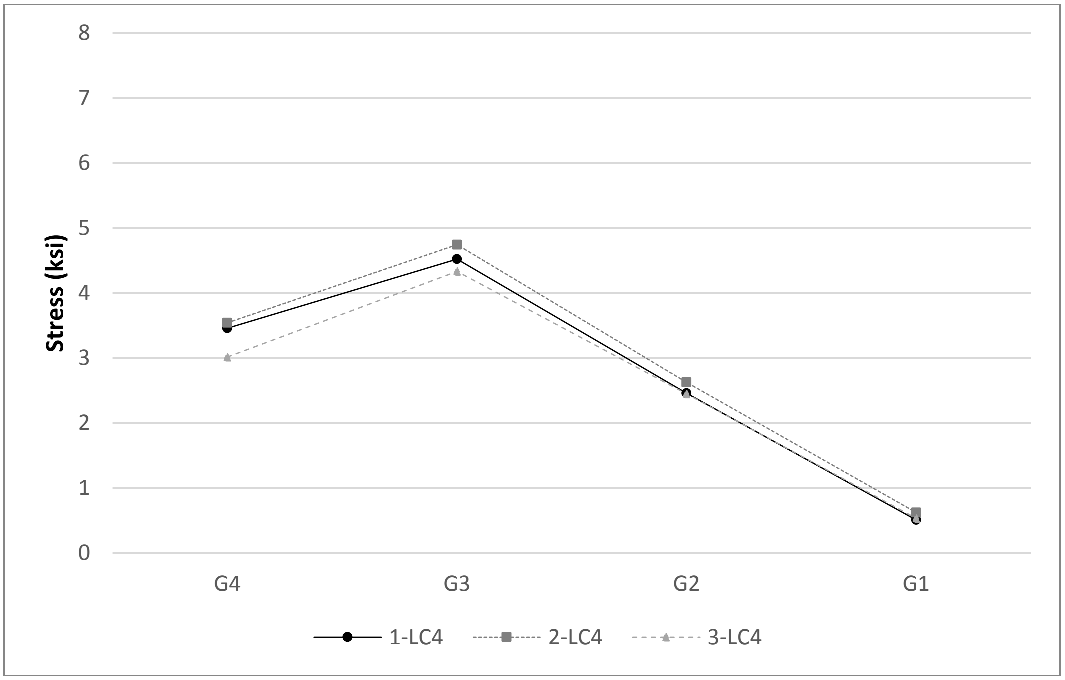


Figure 66. Maximum stress comparison for Load Case 4

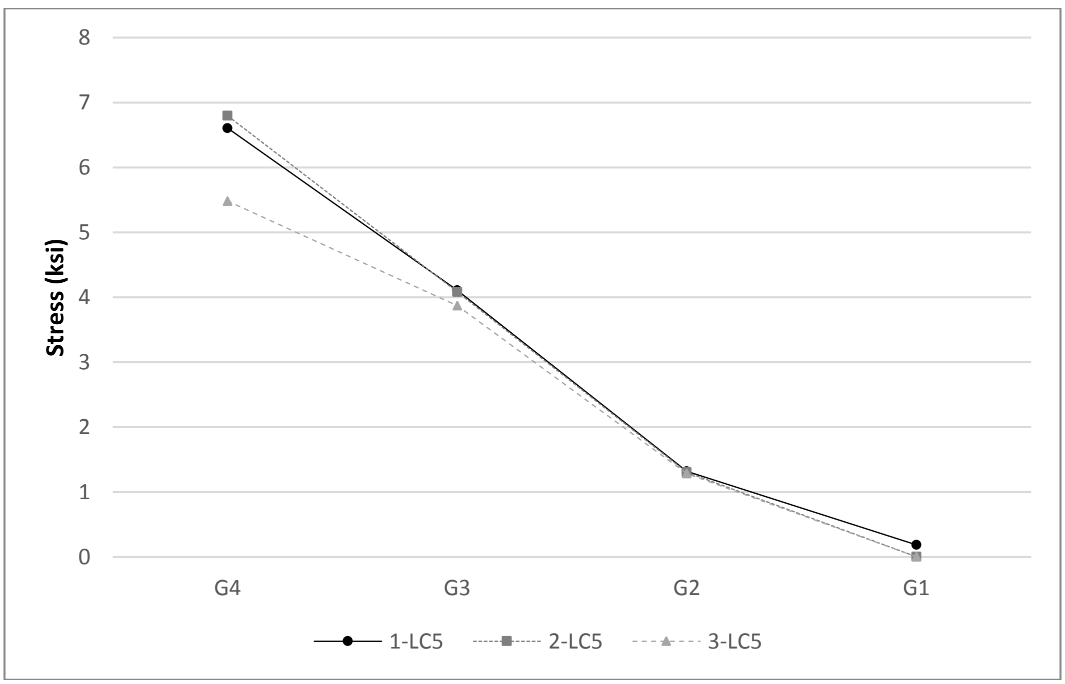


Figure 67. Maximum stress comparison for Load Case 5

One additional plot, which combines Load Cases 2 and 4 to simulate a two-lane-loaded scenario, is shown in Figure 68.

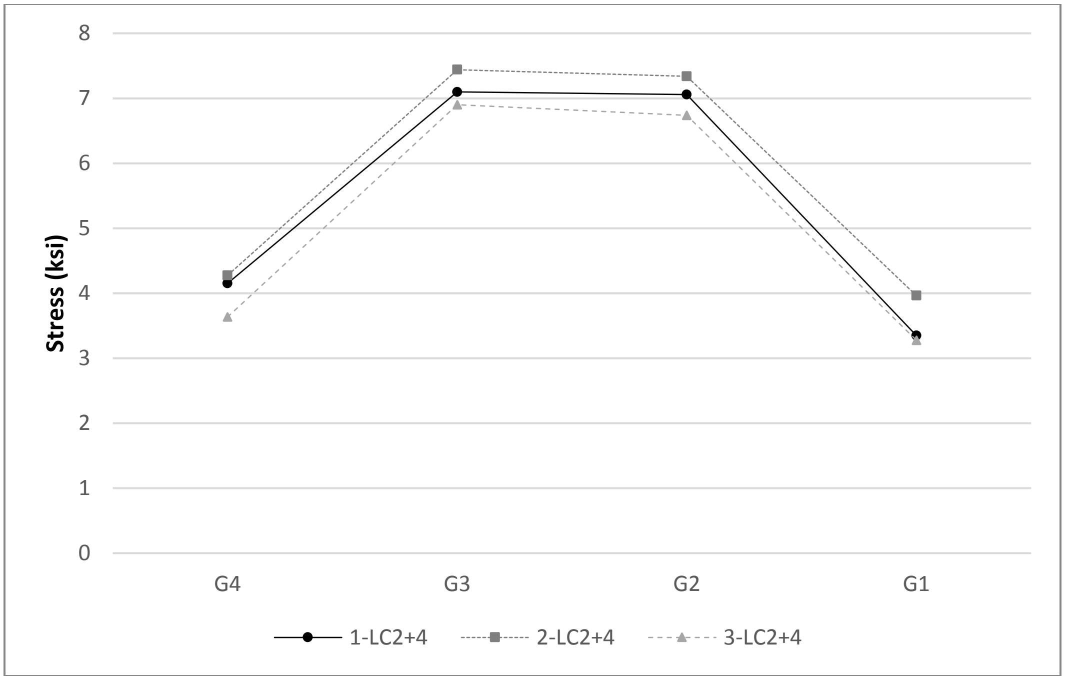


Figure 68. Maximum stress comparison for combined Load Cases 2 and 4

A few things to note when reviewing the results in these plots are as follows. First, the stress values and pattern are consistent among the compared tests, which indicates the bridge performance was unchanged over the 3 years of testing. Second, the maximum stress values remained below 8 ksi for every test, including the combined Load Case 2 and 4 results, well below the yield stress of the steel. So, the researchers expect that the maximum stress would still remain below allowable stress levels with heavier vehicles of other axle configurations. Third, the relative magnitude of stress between girders shows the approximate load distribution across the bridge relative to the transverse truck position. The individual stiffness of each girder is not reflected in these plots, which may slightly change the distribution patterns. Specifically, the deck width attributable to the outside girders is less than the width attributable to the inside girders. However, the uniformity of the section size and deck thickness among the girders would result in similar stiffness values.

Figure 69 shows the load fraction among each of the four girders, which was derived from live load testing in comparison to the distribution factor calculated per the AASTHO bridge design specifications.

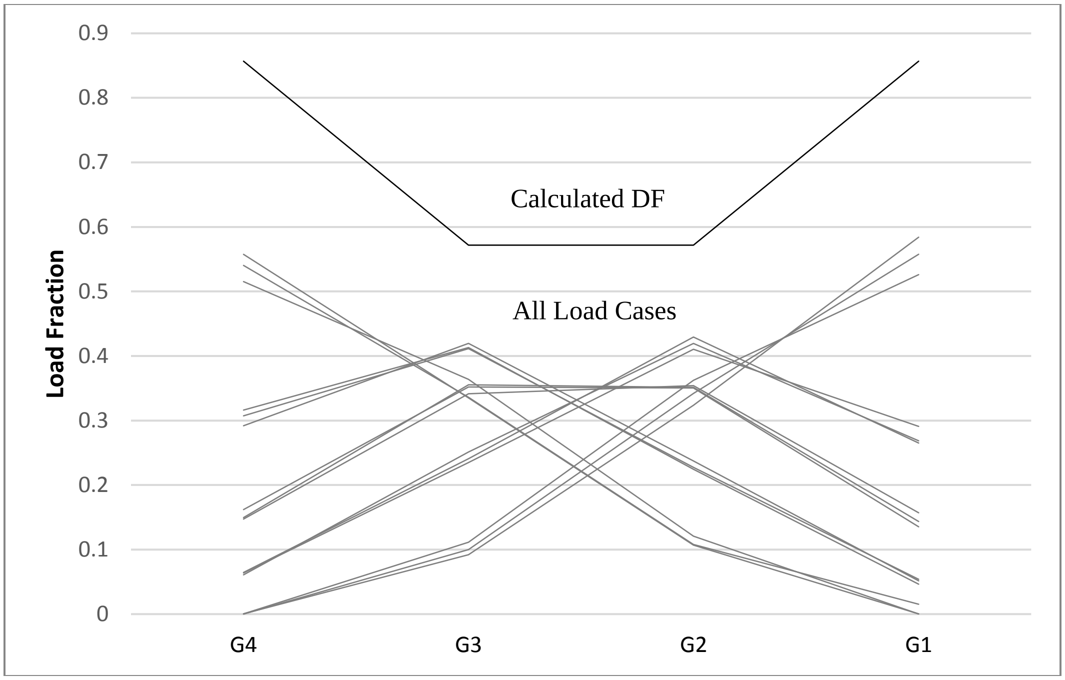


Figure 69. Comparison of calculated distribution factor to load fraction

In every case, the load fraction was less than the calculated distribution factor. This is not unexpected given the researchers' experience with live load testing on numerous in-service bridges where the results would suggest AASHTO LRFD BDS (2020) distribution factor calculations tend to be conservative.

The original development of the distribution factor equations by Zokaei et al. (1991) was extensive and included the study and analysis of several bridge types and configurations. The final distribution factor equations would need to envelope these bridge types resulting in conservative values for some. Furthermore, other factors that influence the in-service load distribution are not accounted for in the design calculations. Examples include unintended continuity/fixity at the girder ends, participation of secondary and nonstructural members, and portions of the load carried longitudinally by the deck.

7 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

7.1 Summary

Steel grades have experienced continual modification and improvement with the goal of developing steel for specific applications. The development and use of A913 Grade 65 steel for the building industry has proven worthwhile, and, recently, the bridge industry has allowed its use by adopting the steel grade into the *Standard Specification for Structural Steel Bridges* under the name A709 Grade QST 65.

It is very likely some of the same benefits realized in vertical building construction can be realized in bridge construction. For that reason, appropriate testing and demonstration was completed to prove the efficacy of this steel for this project.

The primary goal for this project was to evaluate the efficacy of A709 Grade QST 65 steel for use in Iowa bridge projects. In particular, the objectives of the project were as follows:

- 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
- 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, which was constructed using A709 Grade QST 65 steel

A literature review was completed to provide information regarding the recent history, manufacturing process, mechanical properties, weldability, and toughness of A709 Grade QST 65 steel. Laboratory testing of non-composite and composite beams of two different sizes (W24×68 and W30×173) was completed. Furthermore, fatigue testing of numerous samples was completed to define the fatigue characteristics of this steel grade. Lastly, three bridge tests were completed on the newly constructed Sand Creek Bridge to assess whether any changes to the bridge performance were occurring over time.

7.2 Conclusions

A709 Grade QST steel is being increasingly used as a structural steel grade on projects throughout the US and Europe. Its high strength advantages provide opportunities to minimize the structure required for any project 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.

With a reduction in overall steel weight, the costs can be less than they would be otherwise. The adoption of A709 Grade QST steel into the ASTM *Standard Specification for Structural Steel Bridges* in 2018 opens the door to its further use on bridge projects.

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. Minimum requirements for this steel grade have been established, and the results of this study indicate that the requirements were met and surpassed.

In total, four laboratory load tests were completed using two 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. The beams performed very closely to the predicted behavior. The composite tests involved loading the girders beyond the elastic range. A plot of the stress-strain curves indicated a yield strength of the steel to be 72 ksi and 75 ksi for the two beams.

A tensile test was completed on a steel specimen extracted from the girder web to find the yield strength and ultimate strength of the steel grade. The test resulted in a yield strength and ultimate strength of 69 ksi and 86 ksi, respectively. The minimum requirements per ASTM A913 are 65 ksi and 80 ksi, respectively.

Fatigue tests were completed to determine the relationship between cyclic stress amplitudes and the number of cycles to failure. The fatigue limit for Grade 65 QST steel was found to be between 34.50 ksi (largest stress magnitude with no failures) and 37.95 ksi (smallest stress amplitude with failures). Therefore, it was concluded that Grade 65 QST steel could provide adequate fatigue resistance according to current fatigue design provisions.

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. No appreciable changes were observed given that the stress levels within the steel girders imposed by a fully loaded dump truck were consistent between tests.

7.3 Recommendations

The researchers recommend considering the use of A709 Grade QST steel on bridge projects in Iowa due to its high strength and material characteristics directly compared to a more traditional steel grade. Potential cost savings may be realized, especially if 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 and a lot of good and usable information was collected during this project that 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.

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