AISC Student Steel Bridge Competition

Civil Engineering Capstone Spring 2025 Instructor: Khaled Shaaban, Ph.D., P.E., PTOE

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Scope

The following are excerpts from the Student Steel Bridge Competition 2025 Rules.

“Construct a bridge that spans the South Skunk River in Story County, Iowa. The bridge will span a sandbar island in the middle of the river which is home to various wildflowers and birds. This island is a restricted area where no construction activities are to take place.

“The bridge is required to be built of steel because of its design versatility, ease of prefabrication, ability to rapidly erect, superior strength-to-weight ratio, durability, use of 90% recycled material on average, and the steel industry’s commitment to sustainability.”

Objectives

“The Student Steel Bridge Competition (SSBC) increases awareness of real world engineering issues such as spatial constraints, material properties, strength, serviceability, fabrication, erection processes, safety, aesthetics, project management, and cost estimating. Success in competition requires application of engineering principles and theory, effective teamwork, and inclusive practices. Future engineers are stimulated to innovate, practice professionalism, and use structural steel efficiently.

Our objective was to create a working scale model of a steel bridge which performed well structurally and economically, as well as being beautiful and easy to build. This process involved design, fabrication, and timed assembly at the competition.

Alternatives

Through an initial design generation process, we decided on 3 alternatives to analyze for feasibility. The figures below are RAM Elements models, which were analyzed thoroughly. Each had advantages and drawbacks, and we performed a cost estimate for each bridge design.

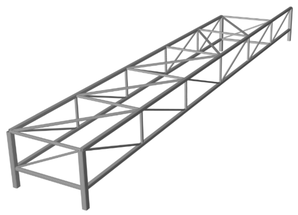


Figure 1 – Alternative 1 - Truss Stringers

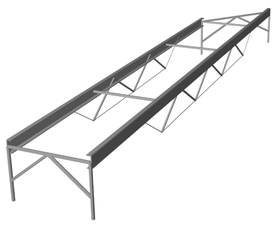


Figure 2 – Alternative 2 - C-Shape Stringers with Under-Truss

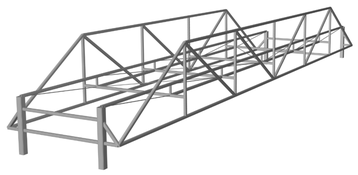


Figure 3 – Alternative 3 - Pony Truss

Fall semester ended with the decision to proceed with Alternative 2. After rigorous analysis, this design with C-shaped stringers and an under-truss yielded the best combination of bridge strength, stiffness, ease of assembly, and fabrication effort.

Alternatives 1 and 3, while achieving low deflection and high stiffness, required prohibitively excessive member quantities and connection complexity. Simplicity drove many of our design decisions moving forward.

Bridge Overview

The bridge consists of two fabricated c-channel stringers. To supplement the bending capacity of the channel, we added a truss-style tension chord below each stringer. We selected this configuration over two other designs that used more elaborate truss systems, but which also involved the use of significantly more members. This design is preferable because there are fewer members and therefore fewer required connections. The relatively heavy c-channel would be offset by fewer members – meaning a reduction in build time while maintaining structural performance. This decision also allows for increased sustainability through common and simple members and connections.

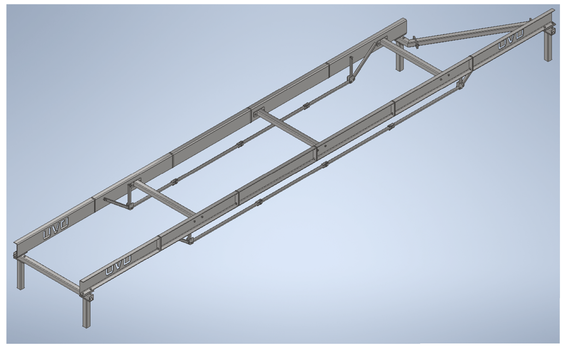


Figure 4 – Bridge modeled using Autodesk Inventor

Connections

The primary connections between the c-channel members are fixed moment connections with two bolts each – allowing the stringers to act as one continuous member. This connection strength is verified in the moment connection calculation shown on the right. Our load testing has also verified that the connections are well suited for their application.

The connections in the tension members are pinned shear connections. The bolts in those connections are were calculated to be well suited for the application.

Analysis

Using RAM Elements structural software, a full structural analysis of the bridge was performed using the given load cases. The structural model was used to check member forces, member stresses, and expected vertical and lateral deflections. The model’s maximum vertical deflection was 1.25”, which was quite close to the measured deflection of 1.5” during our first load test on the constructed bridge.

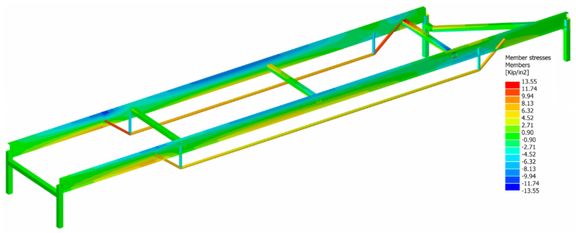
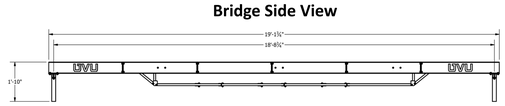


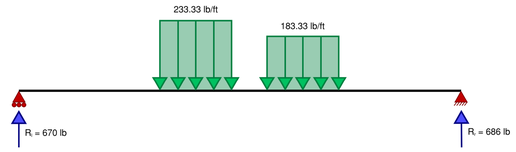
Figure 5 – RAM Elements Model – Member Stresses

Analysis

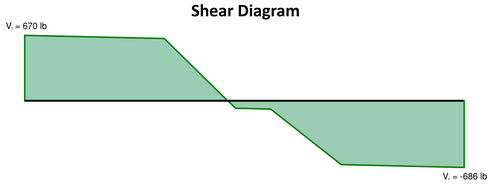
Bridge Side View



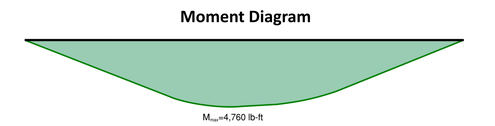
Free Body Diagram (Load Case 7, Stringer Only)



Shear Diagram

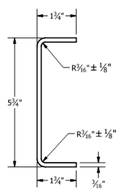


Moment Diagram



Calculations

Stringer



$V_{u3} = 1.7$ kip — Max shear force in member from RAM Model

$M_{u3} = 2.37$ kip * ft — Max moment in member from RAM Model

Shear Check

$V_{n3} = 0.6 \times F_{yplate} \times A_{s3} = 0.6 \times 36 \text{ ksi} \times 1.619 \text{ in}^2 = 34.97$ kip — Shear Capacity

$\frac{V_{u3}}{V_{n3}} = \frac{1.7 \text{ kip}}{34.97 \text{ kip}} = 4.861\%$ — Percent stressed

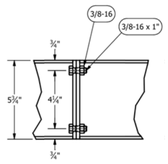
Moment Check

$M_{n3} = F_{yplate} \times Z_{x3} = 36 \text{ ksi} \times 3.180 \text{ in}^3 = 9.540$ kip * ft — Moment Capacity

$\frac{M_{u3}}{M_{n3}} = \frac{2.37 \text{ kip * ft}}{9.540 \text{ kip * ft}} = 24.843\%$ — Percent stressed

Bolts

$M_{max} = 2.37$ kip * ft — Max Moment From RAM Model



$d = 4.25$ in — Distance between bolts

$T_u = \frac{M_{max}}{d} = \frac{2.37 \text{ kip * ft}}{4.25 \text{ in}} = 6.7$ kip — Tension at bolt locations

$b_d = 0.375$ in — Bolt diameter

$b_a = \left(\frac{pi}{4}\right) \times b_d^2 = \left(\frac{3.142}{4}\right) \times (0.375 \text{ in})^2 = 0.110 \text{ in}^2$ — Cross sectional area of bolt

$f_{ybolt} = 120$ ksi — Tensile strength of grade 5 bolts

$\phi R_{nb} = 0.75 \times b_a \times f_{ybolt} = 0.75 \times 0.110 \text{ in}^2 \times 120 \text{ ksi} = 9.9$ kip — Tension capacity of bolt

Design Check

$\frac{T_u}{\phi R_{nb}} = \frac{6.7 \text{ kip}}{9.9 \text{ kip}} = 67.320\%$ — Percent Stressed

Cost Estimate

The cost estimate for the bridge is based on the rules of the competition, but it gives a real-world equivalent for a comparable pedestrian bridge. The input values are the construction time, bridge weight, number of builders outside river, number of builders inside the river (barges), deflection from lateral and vertical load tests, and potential penalties incurred due to rule violations.

Construction Time (min)	13
Bridge weight (lbs)	320
# Builders	2
# Barges	4
Weight Penalties (assume +1%)	3.2
Time Penalties (assume +1%)	0.13
Construction Cost	**$17,199,000**
Load Combination N	**9**
Horizontal Deflection (in)	0.15
Vertical Deflection D1 (in)	1.39
Vertical Deflection D2 (in)	0.9
Aggregate Deflection (in)	2.29
γlat	0.95
Structural Cost	**$12,152,536**
Overall Performance	**$29,351,536**

Table 1 – Cost Estimate

The actual overall performance calculated during the competition was about $30.5M. The difference from estimated to actual was just over $1M and was the closest estimate to actual value in the competition.

Competition Results

The competition was hosted by the University of Arizona in Tucson, AZ. Eight teams competed in eight categories. Our team placed in the top 3 spots in five of the categories:

Construction Speed: **1st Place**
Lightness: 2nd Place
Economy: 3rd Place
Cost Estimation: **1st Place**
Overall: 2nd Place

The team performed very well and are proud of the work that was accomplished. Thanks to Ross Quijano and Zachary Wall for your assistance in the competition!



Figure 6 – Build Team Following Timed Construction

Acknowledgements

Thanks to our faculty mentor, Paul McMullin, S.E., Ph.D., for his excellent advice and guidance throughout this project. Thank you to Pacific Steel & Recycling for donating steel, D&L Supply for providing expert fabrication free of charge, and Petro-Pier whose donation covered fuel costs to transport the bridge to the competition. We’re grateful for the support we’ve received from these industry professionals.