TCNJ 2021 AISC Steel Bridge Competition

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ABSTRACT:

The AISC Student Steel Bridge Supplemental Competition is a national competition that challenges students to design and analyze a scale model steel bridge and the corresponding construction of this bridge. The team designed a Pratt Truss consisting of 20-foot-long stringers, angled lateral bracing, and a total height of 4.87 feet. A "twist and lock" connection was created for the stringers and a sleeve connection for the overhead truss members. The "twist and lock" features a male and female connector where the male swings a "T-Slot" into the female connector. The sleeve connections feature a 1.75" diameter steel pipe with a 0.058" wall thickness, connecting to a sleeve with a 1.634" diameter and a 0.125" wall thickness. Using this design, calculations were completed to estimate vertical deflection, buckling, and other items to ensure stability of the bridge. Overall, this design has a maximum vertical deflection of 0.56", a weight of 240 lbs., 57 members, and 50 connections. In total the final engineering cost for this project has been approximately $122,000.00 with an estimated construction cost of $3,500.

As of April 16, 2020, AISC announced that TCNJ's submission finished first overall in the Metropolitan region ahead of Rutgers University and New York University, and will move on to compete in the national competition.

DESIGN:

Final Bridge Design:

- Four alternative designs were considered for the final bridge design: an under truss, Howe truss, Pratt truss, and Warren truss.
- The alternative designs were modeled in the software *VisualAnalysis*
- The bridges were rated based on their total cost, which was dependent on the aggregate deflection, weight, and construction time. Table 1 shows the average total cost, based on the six load cases, for each alternative design.
- The Pratt truss was selected as the final design due to it having the lowest total cost in the table. A 3D isometric view of the preliminary final design can be seen in Figure 3.

Connection Design 1: (Figures 6 and 7)

- Connection Design #1 is a "Twist and Lock" design used to connect stringers, footing and lateral bracing members together.
- The connection will consist of four parts with two male and two female connectors.
- The bottom connectors will be attached first by dropping the male connectors disk into the female connector.
- The top male T- Slot connector will swing horizontally into the other stringers female connector.
- The bottom male connector has a small strip extruded out that the members will be capable of rotating, but large enough that the void space between the two members will be eliminated when it is rotated 90 degrees.
- This connection will be used 34 times in the design.
- Additional to members for the bolt requirement that will be offset 1.5" from the center of the stringers allowing a four inch steel bolt to be assembled through two of these apparatuses.

Connection Design 2: (Figure 8)

- Connection Design #2 is a sleeve design used to connect the overhead truss members.
- This design was selected to minimize the weight of the bridge by using a hollow connection.
- The overhead truss is under less stress than the stringers allowing us to use a weaker connection.
- Each member of the overhead truss will have a side which is slightly smaller than the pipe allowing it to slide into another member.
- This sleeve will have a total length of five inches with three inches welded inside the pipe and two inches extruding. This connection will be used 16 times in the design.
- The team decided to construct another external member to meet the bolt requirements that will consist of 4" of ¼" diameter steel and 2" of ⅜" diameter steel.
- Allowing a four inch steel bolt to be assembled through two of these apparatuses eliminating any void space.

DESIGN CONSTRAINTS:

Loading:

- The bridge was subjected to a vertical load test and a lateral load test.
- The bridge was subjected to a uniformly distributed load of 1500 lbs. and 1000 lbs. over three feet and a 50 lbs. lateral force.

Size/Dimensions:

- The total height was 4.87 feet above the ground and each stringer was between 3'-0" and 3'-6" feet long.
- The four footing boxes were 1' x 1' and offset by 1.5 feet on each side (Figure 1).

Site Layout:

- The competition site was split into a right yard and a left yard, both yards contain tools, nuts, bolts, and builders and only the right yard was permitted to store bridge members.

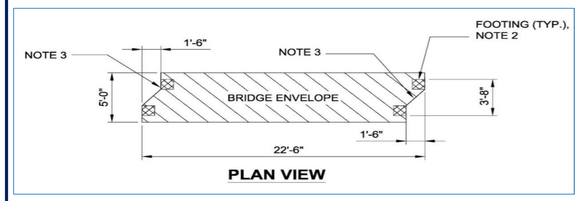

Figure 1 – Bridge Envelope

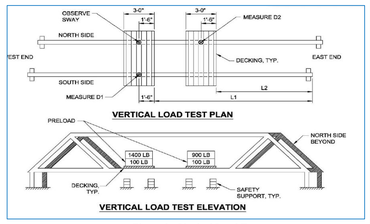

Figure 2 - Vertical Load Test

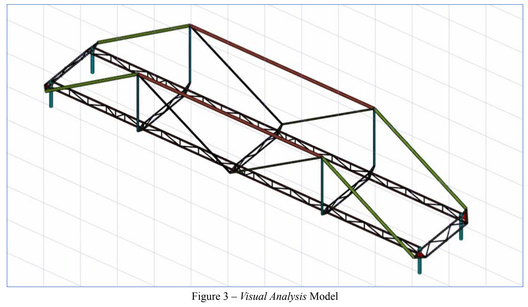

Figure 3 – *Visual Analysis* Model

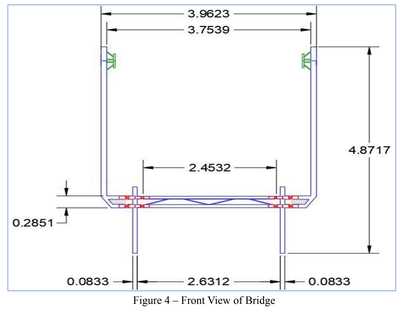

Figure 4 – Front View of Bridge

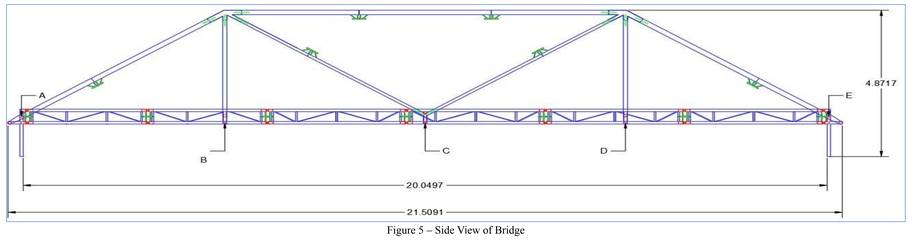

Figure 5 – Side View of Bridge

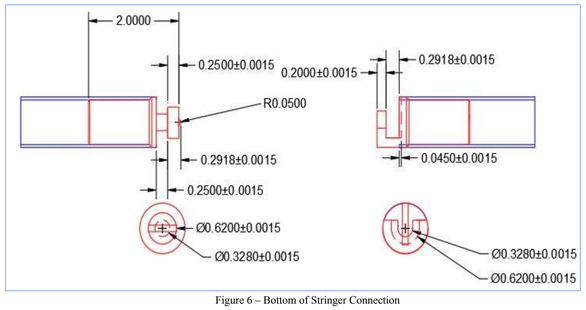

Figure 6 – Bottom of Stringer Connection

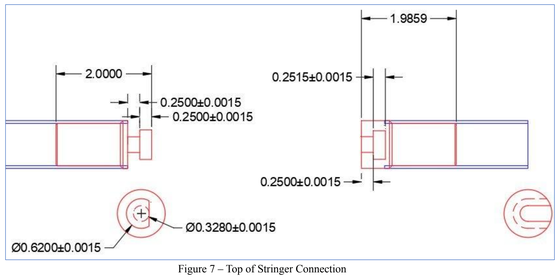

Figure 7 – Top of Stringer Connection

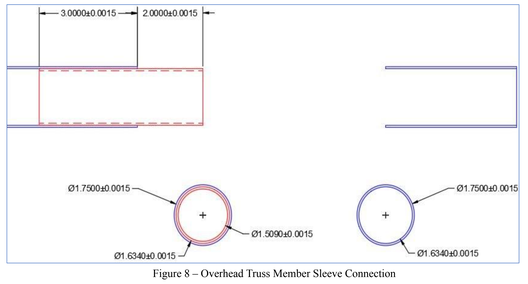

Figure 8 – Overhead Truss Member Sleeve Connection

RESULTS:

Table 1: Alternative Design Evaluation

	Aggregate Deflection (In.)	Weight (lbs.)	Structural Cost ($)	Construction time (minutes)	Construction Cost ($)	Total Cost ($)
Howe Truss	0.34	254	$1,703,000	8.3	$2,324,000	$4,027,000
Pratt Truss	0.29	256	$1,561,500	8.3	$2,324,000	$3,885,500
Warren Truss	0.31	259	$1,648,500	8.63	$2,417,333	$4,065,833
Undertruss	0.77	231	$2,873,500	5.82	$1,628,667	$4,502,167

Table 2: Hand Calculated Results

Maximum Shear (Kips.)	Maximum Moment (kip.-ft)	Aggregate Deflection Range (In.)	Weight of Connections (lbs.)	Weight of Bolts (lbs.)
0.78	4.67	0.148 to 5.51	60	13.25

Table 3: Hand Calculated Buckling Results

General Buckling		Flexural Buckling	
Capacity (kips.)	Max Force (kips.)	Capacity (kips.)	Max Force (kips.)
2.2	1.36	1.94	1.36

CONSTRUCTION SEQUENCING:

Construction Sequencing:

The bridge would be assembled in the order of footings, stringers, middle bracings of the lower truss, overhead truss assembly, and finally the bracings for the overhead assembly. The building process from bottom to top would provide for the greatest stability of the structure as upper members are attached. As each member is installed, the ideal sequence would require the builder to immediately secure the connection with a bolt. The purpose of this would be to eliminate any slack that could be found in the joint and allow for easier handling as the assembly grows larger. Tools, Nuts and Bolts, are in both staging yards, while the bridge members are located only in the right staging yard.

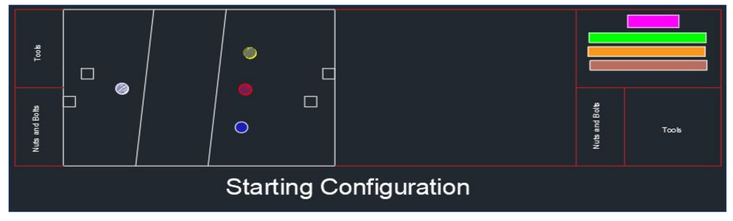

Figure 9: Starting Configuration for Construction

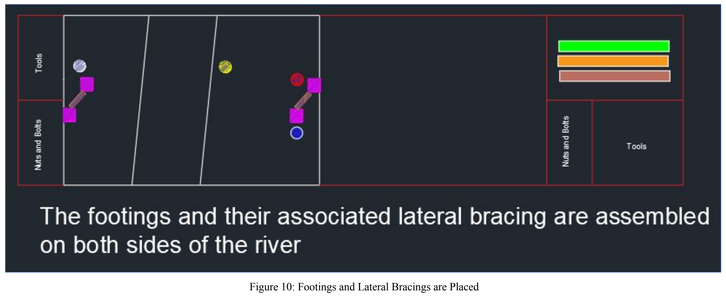

Figure 10: Footings and Lateral Bracings are Placed

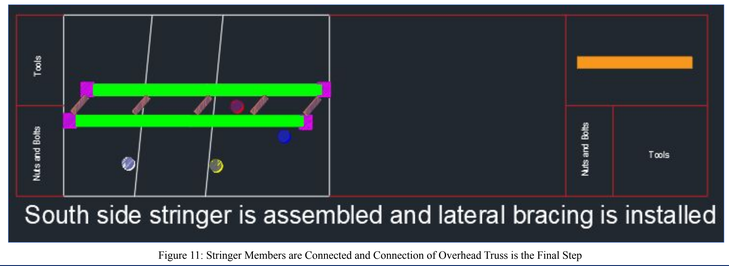

Figure 11: Stringer Members are Connected and Connection of Overhead Truss is the Final Step

References:

(1) AISC Steel Bridge Competition Rules
(2) "VisualAnalysis V18 Edu." (2019). *Home - VisualAnalysis*, IES, Inc.,

Acknowledgment:

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