USU STEEL BRIDGE DESIGN

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SUMMARY
Utah State University Steel Bridge (USUB) has designed a bridge to compete at the American Institute of Steel Construction (AISC) Student Steel Bridge Competition. The design process involves the analysis of many bridge alternatives to determine the most cost-effective bridge design. USUB analyzed both an under-span and over-arch bridge design based on weight, number of members, ease of fabrication, ease of construction, and vertical deflection. USUB found the over-arch bridge design to be the recommended alternative because of the minimal deflection it experiences under load compared to an under-span bridge.

USUB completed an in-depth analysis using RISA 3D to design two over-arch bridges. The final bridge design minimized deflection while increasing weight and construction time in a cost-effective manner. USUB then drafted each individual member in AutoCAD. Fabrication of the steel bridge was completed by GWI Steel and USUB. The USU Steel Bridge received 2nd place overall at the regional competition, earning a spot at the national competition.

DESIGN CRITERIA
USUB received dimensional and construction parameters from AISC to design a steel bridge. The bridge is to be modeled to represent a railway bridge in a Hawaiian mountain region. The area in which the bridge is located prevents the bridge from having typical footings; therefore, one footing needed to be offset towards the center of the bridge as seen in Figure 1. The bridge is span 23 feet, has a depth of no more than 5 feet, and has a clearance of 3 feet and 7 inches in the center width of the bridge. After bridges have been constructed, a load of 2500 pounds is placed on the bridge. The location of the loading is determined just prior to the start of competition.

ALTERNATIVE EVALUATION

I. Alternatives. Multiple alternatives were originally considered for the USU Steel Bridge design. USU Steel Bridge originally performed a cost-benefit analysis between an under-span and over-arch bridge design. Different scenarios were considered between the two designs, and it was determined that the over-arch bridge would produce the best performing bridge. Based on the scoring set forth by AISC, the total weight, vertical deflection, and construction time all factor into the total cost of the bridge. While USUB tried to accommodate all of these factors, analysis determined that deflection is weighted more heavily in the final cost; therefore, deflection was the primary concern.

II. Final Two Designs. After deciding on the over-arch bridge, USU Steel Bridge designed two over-arch bridges as seen in Figures 2 and 3, in RISA 3D in order to determine the most effective design. Design 1 and design 2 are very similar in the bottom chord design but differ in the top chord design. Bridge 1 design is a true arch design where the top chord experiences only compression and the vertical members between the top and bottom chord experience both tension and compression. Design 2 is a truss design that experiences compression on the top chord and only tension on the vertical members. Bridge design 2 was selected as the final design based on a lower bridge deflection, a more simple fabrication design, and a faster construction time.

FINAL BRIDGE DESIGN

I. Bridge Configuration. The bridge is designed with an over-arch top chord in addition to a smaller truss system on the bottom stringer. The bottom stringer and over-arch top chord are connected with eight tension members. Lateral bracing is applied to both the top chord and bottom stringer. This configuration was chosen to minimize deflection while keeping weight and construction time at a minimum.

II. Accelerated Bridge Construction. Connections between bridge members are designed to facilitate the fastest construction time possible. Bottom stringer and top chord connections are designed to slide into place and be self-supporting before a bolt is placed in the connection. AISC requires each connected member to have at least one bolted connection. The bottom chord consists of two different connections called the USU and Tiger Tooth connections as seen in Figures 4 and 5. The Tiger Tooth connection is placed on the bottom of the bottom chord with a bolt through the center. The USU connection is placed on the top of the bottom chord and slides into itself without a bolt attached. The top chord connection uses a simple male/female slip connection. The members are then fastened together with conjoining angle iron tabs with a bolt and nut connecting both members together.

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III. Build Sequence. The bridge is designed to be built sequentially to minimize construction time. The sequence in order of assembly is 1) footings, 2) bottom stringers, 3) top chord, 4) lateral members, and 5) tension members. The build team consists of 5 members: 2 on the short side of the construction zone and 3 on the long side of the construction zone. The bridge has the entire bottom stringer and footings assembled and standing on its own before the top chord is built. Following the assembly of the top chord, the lateral members and tension members are connected.

COMPETITIONS

I. Regionals. USU Steel Bridge competed against ten schools within their region in April at University of Boulder Colorado. USU Steel Bridge’s design weighed 243 lbs, was built in just over 15 minutes, and had an aggregate deflection of 1.13 in. USU Steel Bridge took 1st in aesthetics, 3rd in construction speed, 1st in stiffness, 2nd in economy, 3rd in lightness, and 2nd overall at the AISC regional competition in Colorado.

II. Nationals. USU Steel Bridge will make adjustments to their bridge in order to increase stiffness, decrease weight, and improve build time in preparation for the national competition. The national competition will be held at Southern Illinois University in May.

Figure 1. Construction Zone for the Bridge

Figure 2. Design 1

Figure 3. Design 2: Final Bridge Design

Figure 4. Tiger Tooth Connection

Figure 5. USU Connection

Figure 6. 2019 Senior Design Team

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