COMPETITIVE STATE-OF-THE-ART STRUCTURAL ENGINEERING

DESIGN AND MANUFACTURING OF STEEL BRIDGES IN THE ALASKA ARCTIC

FINAL PROJECT REPORT

by

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Table of Contents

List of Figures

List of Tables

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Abstract

The University of Alaska Fairbanks (UAF) steel bridge team had an exceptional year, largely due to the chemistry of the team and to financial backing at all levels. The team won the regional competition and placed ninth at the national competition. In addition to competing with other universities, the UAF steel bridge team also worked on community service projects, including raising money for food and building beds for a family in North Pole, Alaska.

Executive Summary

The annual steel bridge competition was created over two decades ago to foster excellence and ingenuity among civil engineering undergraduate and graduate students across the nation. The steel bridge competition is one of many great opportunities to get involved in extracurricular activities associated with the civil engineering field. The University of Alaska Fairbanks (UAF) has a long history of strong performance; it is known for placing well in both the regional and national competitions. Students design and manufacture 1/10-scale bridges with which they compete in a regional competition and, if successful, a national competition. The Pacific Northwest Regional Conference is usually held in mid-April each year. Much preparation and work leads to this high point of each competition year. The steel bridge competition teaches students useful skills that few other engineering students have the chance or ability to learn. These lessons contribute to making steel bridge team members valuable employees for future employers. Together, students tackle technical work and overcome financial trials and tight deadlines under conditions such as sleep deprivation and strenuous class loads. The 2015 competition was held at Idaho State University in Pocatello, Idaho. The UAF steel bridge team swept the regional competition, winning seven out of seven categories, and competed for the national title on May 23 in Kansas City. In addition to designing and building a steel bridge, members of the team completed hundreds of hours of community service and public speaking. They support and comprise the core of the UAF Associated General Contractors and American Society of Civil Engineers student organizations. Steel bridge members sacrifice time with loved ones as well as sleep and time allotted for homework in order to achieve one common goal: to design and manufacture the best bridge in the Pacific Northwest.

Chapter 1 Introduction

1.1 What is the Steel Bridge Competition?

The annual steel bridge competition is organized by the American Society of Civil Engineers (ASCE) to foster excellence and ingenuity among civil engineering undergraduate and graduate students across the nation. Membership in the ASCE is free for students and comes with many benefits. The ASCE provides excellent opportunities for networking and professional development and access to a wide variety of cutting-edge publications and journals. The steel bridge competition is one of many great opportunities for students to get involved in extracurricular activities associated with the civil engineering field.

The regional steel bridge competition is held at the ASCE regional student conference, in conjunction with a concrete canoe competition, an environmental challenge, a transportation challenge, and a technical paper competition. Most of these competitions are stand-alone ones, but the University of Alaska Fairbanks generally participates in all five competitions with great success. The top schools from each regional conference get invited to the national steel bridge competition, which this year was held at the University of Missouri – Kansas City. As mentioned before, each competition is a stand-alone one, but submission of a technical paper is required as part of qualifying for the national steel bridge competition.

The University of Alaska Fairbanks (UAF) has a long history of strong performance at the steel bridge competition. Known for placing well in both the regional and national competitions, UAF earned national champion in 1993 and seldom places lower than the top 20 competitors in the nation out of more than 200 competing schools. Many of these universities are prestigious engineering schools, such as the University of California – Berkley, the University of

California – Davis, and Michigan Institute of Technology (M.I.T.). These universities have large budgets and outside contractors that do some or all of the manufacturing. Students at UAF proudly complete the entire process in-house, from fundraising to design and fabrication.

The steel bridge competition's rules and specifications are made official (distributed) early in September. The steel bridge team's focus for the entire design and manufacturing process is based on these specifications (the official rules). Similar to real-world projects, regulations and industry standards govern the final product. The rules can best be described as a bid document for a river crossing, where the site conditions and the desired bridge performance specifications are clearly outlined. The bridge is designed and manufactured to 1/10 scale according to the specified requirements of overall span (in order to cross the river), the required vehicle passageway and lane width (to make sure that vehicles and semi trucks will be able to pass when crossing the bridge), the largest possible member size (to be able to transport the pieces to the site based on local road restrictions and equipment assembling the bridge), and the approved types of connections. Considerable emphasis is placed on accelerated bridge construction (ABC) to save money and time during manufacturing and assembly of the bridge on-site.

Three main factors affect the final score of the 1/10-scale bridges in the competition: weight of the bridge (pounds), stiffness of the bridge (aggregate deflection measured in inches at three locations and summed to create the aggregate deflection used for scoring), and the time it takes to assemble the bridge (minutes). These three factors (weight, stiffness, and assembly time) are entered into a formula that converts to a dollar amount. The bridge that meets all the required specifications and has the lowest calculated dollar cost wins the competition. The factors used to determine the score simulate that of a real-world low-bid process. The weight represents the material cost (structural steel is priced per pound of material); the time required to assemble the 1/10-scale bridge at the competition simulates the number of work hours (labor cost) required to erect a full-scale bridge; and the stiffness of the 1/10 scale ensures proper serviceability of the full-size bridge. Engineers need to design structures not only to be sufficiently strong, but also to serve clients' needs. Humans generally feel uneasy if large deflection is sensed (regardless of the actual strength of the structure). An example of this may be the attic of an old wooden house, where the floor joists creak and deflect causing unease despite their being adequately strong to support the load. Serviceability (deflection) is an important factor in considering a design; hence the steel bridge rules force engineering students to meet certain deflection targets with their bridge design.

1.2 Why Participate in the Steel Bridge Competition?

The steel bridge competition challenges and inspires students. It is easy to design a bridge that will be adequately strong, but far less easy to design a highly competitive bridge for the national arena. The steel bridge project prepares students for the world outside of academia. Traditional academic education is valuable and important in today's competitive work environment. However, some traditional degrees fail to give students real-world experience and the skills necessary to prepare them for successful professional development. Engineering degrees help students develop problem-solving approaches to almost any task. The steel bridge competition helps students gain important skills that traditional academic education sometimes fails to offer, skills such as machining, welding, designing, fundraising, community involvement, public speaking, project management, and teamwork. The steel bridge competition is an excellent opportunity for students to gain experience by seeing an entire project through, from start to finish. It is especially beneficial to manufacture what you design. Participants in the steel bridge competition develop a keen mind for innovative problem solving and a strong work ethic. Participation requires late nights, early mornings, all-nighters, and everything in between to complete the design and manufacturing of a competitive bridge. It is not uncommon for students to spend over 100 hours of their spring break, and 40–60 hours a week throughout spring semester working on the bridge. Manufacturing requires close to a 24/7 commitment during the last weeks before the competition. Students volunteer to come to the shop at 2 a.m. to pull a night shift or stay all afternoon and into the night until class starts in the morning at 8 a.m. The steel bridge competition opens doors for future employment through the networking and community involvement required to fundraise for the program each year. Employers recognize this drive and motivation to excel, often seeking out steel bridge participants for future hire.

1.3 My Experience with the UAF Steel Bridge Team

My involvement with steel bridge competition began in 2013, after becoming friends with some of the key bridge members through the UAF Ice Arch construction. The 2013 UAF steel bridge (designed by Pat Brandon) dominated at the regional competition by winning the following categories (the categories in parentheses are separate side competitions):

Regionals	**Nationals**
1st place Structural Efficiency	3rd place Structural Efficiency
1st place Stiffness	3rd place Deflection
2nd place Lightness	(1st place Tug-of-War)
2nd place Construction Economy	
(1st place Environmental Engineering Competition)	
(2nd place Transportation Engineering Competition)	
(Overall Engineering Excellence Award)	

Figure 1.1 Assembly of the 2013 bridge at the national competition.


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Figure 1.2 2013 UAF steel bridge team posing with awards.

The 2014 steel bridge (designed by Will Riley) was a structural masterpiece that required a tremendous amount of work to manufacture and weld. Over 700 individual pieces were milled and machined to a precision of 1/1000 of an inch, and at least 1500 welds were completed. Due to the amount of work required, both day shifts and night shifts were scheduled in the machine shop to keep the machinery on the critical path. The time commitment was considerable for students who already were spending over 80 hours a week attending classes and finishing school assignments. The 2014 bridge would most likely have won both the regional and national competitions had there not been a local buckling failure that caused welds to break.

Figure 1.3 The 2014 UAF steel bridge at the regional competition at Portland State University.

The rules for the 2015 steel bridge competition were similar to the rules in 2014. The dimensional specifications and the loading were nearly identical. The major changes in the rules were the overall span (18.5 feet instead of 17 feet) and more freedom to design innovative and quick-to-assemble connections. The 2015 bridge (designed by Daniel Hjortstorp) sported a delicate lower chord spanning 19.5 feet, along with a stout 1-3/4 inch upper chord. The bridge had a clearance of 19 inches over the river and a total height of 59 inches. Just as in previous years, the bridge was manufactured out of 4130 chrome molly steel and assembled with aircraft-quality nuts and bolts. Much attention and time were given to designing and manufacturing state-of-the-art connections for the bridge to allow for quick assembly. Members in the space truss were standardized to accelerate the manufacturing process.

Figure 1.4 The 2015 UAF steel bridge timed-assembly practice (regional competition in Pocatello, Idaho).

Figure 1.5 The 2015 UAF steel bridge build team (after the timed assembly).

The steel bridge project has provided an extraordinary opportunity for unmatched experience and for developing skills and friendship. In 2013, I learned to use the equipment in the machine shop and competed with the UAF steel bridge team as one of four builders at both the regional and the national competition. In 2014, I was assigned as the student in charge of steel bridge manufacturing, and in 2015, I designed the bridge and led the team as its captain. It has been an unforgettable journey, full of hard work, lasting memories, and laughs. The experience has contributed more to my academic development than both coursework and traditional academic learning. I am forever thankful for the opportunity to participate in the UAF steel bridge program and look forward to becoming a strong alumni supporter.

Figure 1.6 The 2015 UAF steel bridge team.

Chapter 2 Method

2.1 Recruiting Interest, Fundraising, Charity, and Community Involvement

Recruiting is one of the most important activities in building and maintaining a competitive team. As team captain, I found that developing interest in the steel bridge project among fellow students and classmates was a constant task. Our team spent countless hours advertising and promoting the steel bridge team at our weekly joint meetings with the ASCE and the AGC student organizations. We took every opportunity to meet and get to know first- and second-year students. We arranged barbeques and talked to first-year classes such as ES101 and surveying for engineers. We also spent time building relationships with local businesses, trade organizations, and professional organizations such as the Chamber of Commerce, Rotary, the Society of Structural Engineering, and the American Concrete Institute, through community service and public speaking. We collected close to 1200 pounds of canned food for the canned food drive one weekend and built bunkbeds for homeless people in North Pole, Alaska, just to mention some of the team's community service. Together, the students that were part of the steel bridge team fundraised $50,000 for the 2015 steel bridge competition, to cover the expenses of materials, travel, and equipment, and for machinery to maintain the shop (see Appendix B for more information regarding the fundraising efforts).

2.2 CAD Design and Analysis

The 2015 steel bridge rules were made available in September, after which the design process was started. The design process is tedious due to the competitive component of the project. It is easy to design a bridge that will be adequately strong, but it requires an exhausting amount of iterations to develop a competitive design. The first step of any design is to carefully examine and read the bid packet and specifications (in this case the 35-page-long packet of competition rules). The design of the bridge is, in large part, governed by the dimensional specifications and calculated score scale outlined in the rules. The rules change each year, making it important to carefully examine the most current rules for changes. The rules commonly outline a mission and summary:

> Civil Engineering students are challenged to an intercollegiate competition that supplements their education with a comprehensive, student-driven project experience from conception and design through fabrication, erection, and testing, culminating in a steel structure that meets client specifications and optimizes performance and economy. The Student Steel Bridge Competition increases awareness of real-world engineering issues such as spatial constraints, material properties, strength, serviceability, fabrication and erection processes, safety, aesthetics, project management, and cost. Success in competition requires application of engineering principles and theory, and effective teamwork. Future engineers are stimulated to innovate, practice professionalism, and use structural steel efficiently" … The Student Steel Bridge Competition provides design and management experience, opportunity to learn fabrication processes, and the excitement of networking with and competing against teams from other colleges and universities (2015 National Steel Bridge Student Competition, 2015).

The 2015 (simulated) problem statement was set forth by President Kupicra, who requested a bridge over the Nogo River to encourage commerce between farming villages and the capital, H'sogo. Bridge materials had to be transported on oxcarts during the dry season, making accelerated bridge construction (ABC) essential to achieve completion before the rainy season. There are several categories in the competition: aesthetics, construction speed (timed assembly at the competition), lightness, stiffness, construction economy, structural efficiency, and most importantly – overall performance (which determines the winner of the competition). Most of these categories are self-explanatory.

Construction speed is the time it takes to assemble the bridge at the competition, with time penalties added. Each connection violation adds three minutes to the overall score, hence ruining the low score of a bridge significantly. Lightness is awarded to the lightest bridge after weight penalties have been added. Dimensional violations may add 50 to 200 pounds to the original weight of the bridge. Similarly, stiffness is a simple measure. There are six different load cases (determined by the roll of a dice before the competition begins), at which three deflections are taken and added to an aggregate deflection.

Table 2.1 The six load cases along with deflection targets.

S	T1	T2	L1 (lb)	L2 (lb)
1	9′9″	12′3″	1000	1400
2	7′9″	9′9″	1400	1000
3	7′9″	12′3″	1200	1200
4	7′3″	10′9″	1200	1200
5	7′3″	11′9″	1000	1400
6	9′3″	11′9″	1400	1000

(S=Loadcase, T=Deflection Target, L=Load)

Construction economy is calculated from the construction speed by taking the time to build the bridge times the number of builders that build the bridge. The maximum number of builders is 6, and the maximum construction speed (straight time) allowed is 30 minutes. Construction economy is calculated as follows: *Construction Economy = Total Time (minutes)* × *number of builders (persons)* × *50,000 ($ per person-minute) + load test penalties ($).*

Hence, a bridge built in 20 minutes by 4 builders would score $4,000,000 in the construction economy category, provided there were no penalties. One of the larger penalties this year was associated with the river at the simulated construction site at the competition.

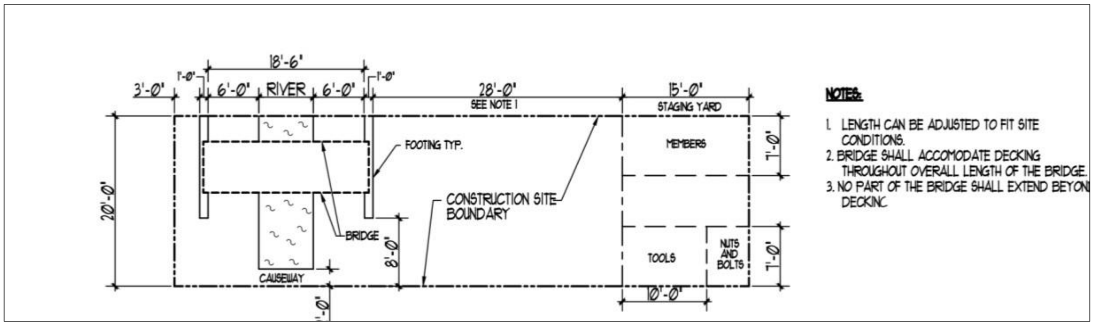

Figure 2.1 Construction site plan (at the competition).

Structural efficiency is the second major category that determines the overall score of the bridge. Structural efficiency is calculated with the following formula (for bridges weighing less than 400 pounds): *Structural Efficiency = Total Weight of the Bridge (pounds) × $20,000 ($/pound) + Aggregate Deflection (inches) × $1,000,000 ($/inch) + load test penalties ($).*

There is a separate formula for bridges weighing more than 400 pounds. However, bridges that heavy are not competitive in the national arena, thus the formula will not be covered in detail. Overall performance is calculated by adding construction economy and structural efficiency (determining the winner of the competition).

The design of each bridge should be based on the details just described in order to be competitive. A bridge that is highly competitive one year may not be competitive in the following years due to rule changes; therefore, designers are encouraged to develop new, innovative, and competitive designs each year based on countless simulations in structural analysis programs and material research.

The design process takes considerable time. The first stage is comprised of careful examination of the rules. Each detail and change is carefully analyzed to find areas that may allow for improvements and advantages over other schools. Inadequate familiarization with the rules is one of the most common mistakes made by participating schools. Special care has to be taken to ensure that assumptions are not made based on mixing up the rules of previous years with those of the current year. Once the rules have been carefully analyzed, a process is started in which every single bridge shape imagined is drawn as a stick figure and analyzed in structural analyses programs. We currently use RISA, Version 12, a powerful structural analysis program, to analyze our designs. The following figures show some of the designs that were analyzed in the initial design phase.

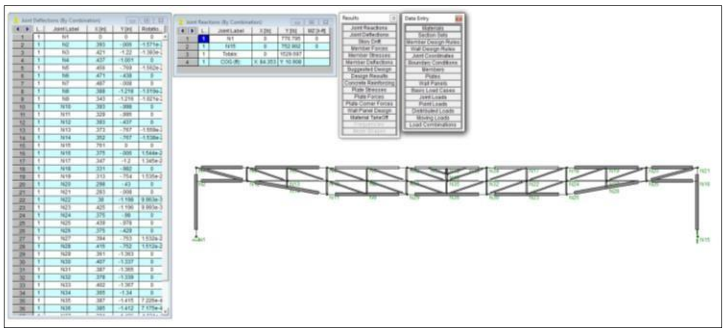

Figure 2.2 Early prototype of an undertruss bridge analyzed in RISA.

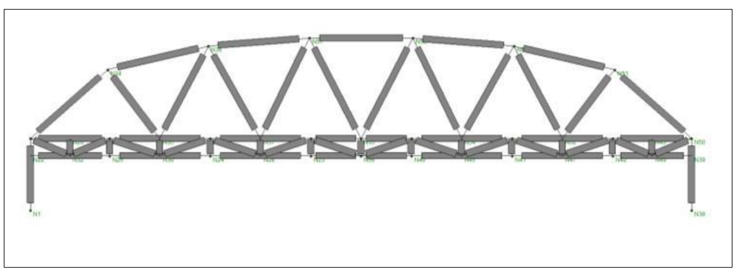

Figure 2.3 Overtruss analyzed in RISA.

RISA shows the deflection and stress of each member and joint, along with the overall weight of the structure, making it a powerful analysis tool. Once the final shape of a bridge is determined—based on 2-D analysis—the bridge is drawn in 3-D in AutoCAD and imported into RISA 3-D for further analysis and optimization.

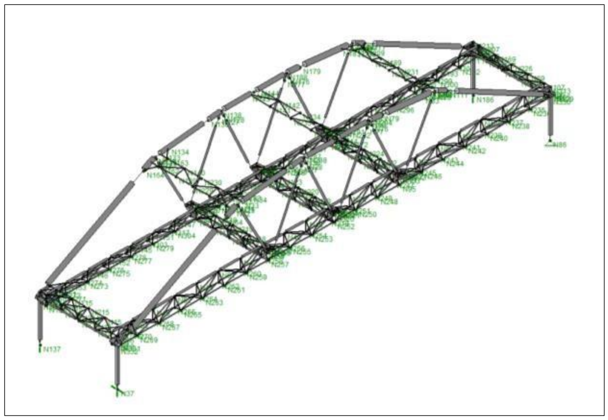

Figure 2.4 RISA 3-D analysis of an overtruss bridge.

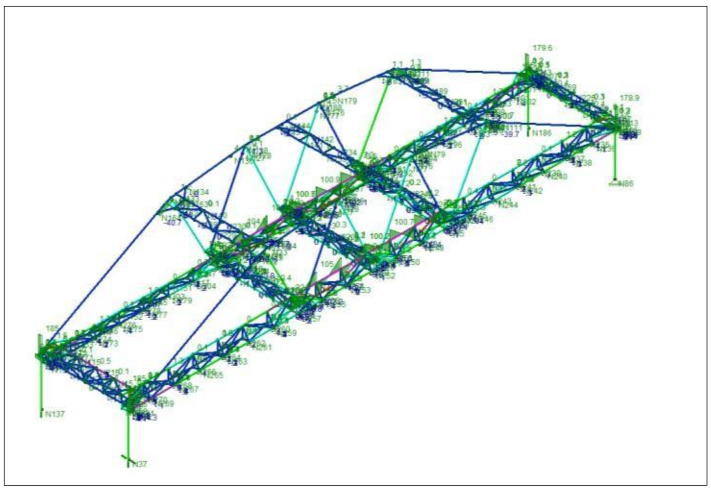

Figure 2.5 RISA has many settings for changing the material properties and for careful analysis of the stress and deflection of members. This picture shows the tension and shear in the bridge based on 2500 pounds distributed across 6 feet at the center of the bridge.

Design and manufacturing requires a lot of effort. As James Dyson once said, “Manufacturing is more than just putting parts together. It’s coming up with ideas, testing principles and perfecting the engineering, as well as the final assembly” (Arrasmith, 2015).

Altogether, over 400 files of different designs and modifications to the 2015 steel bridge were created throughout the design period between September and February. Once the overall shape of the bridge had been determined and the material and sizes assigned to each member (members could only be 36 inches long), much time was spent designing quick-to-assemble connections with sufficient strength. The connections were drafted in AutoCAD, after which they were analyzed with the help of Autodesk Inventor and Autodesk Simulator. Autodesk Simulator is a finite element analysis program that analyzes stress and displacement by breaking elements into very small increments. These programs are accurate, but the output is only as good as the input; hence, it is important to verify the results with real data. We tested a T-slot prototype and many other connections in a straight tension test. The graph for the results can be seen in Figure 2.6.

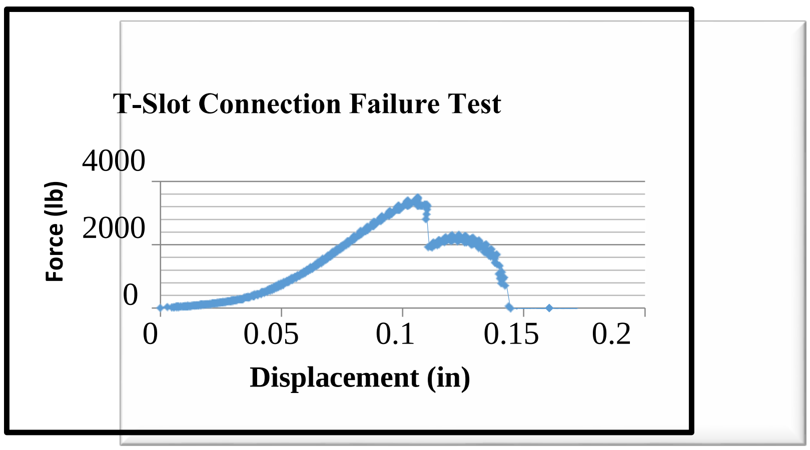

Figure 2.6 Tension test of a prototype T-slot connection.

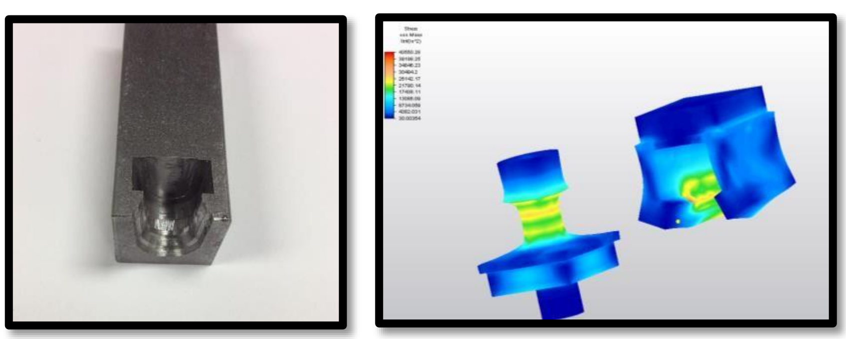

Figure 2.7 Prototype T-slot and Autodesk simulation results (the deflections are exaggerated in the visual output results).

Once the final bridge design was created, the concept was turned into a workable format. The entire bridge, consisting of over 300 individual members, was broken down into separate pieces, and shop drawings were created. The shop drawings have to convey enough information to machine each individual piece. Figure 2.8 illustrates a basic overview of the bridge before breaking it into smaller pieces.

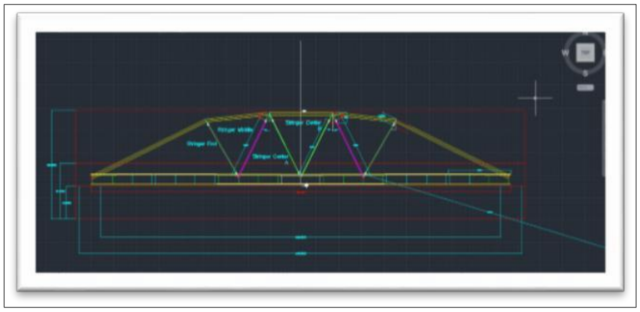

Figure 2.8 Final bridge design overview.

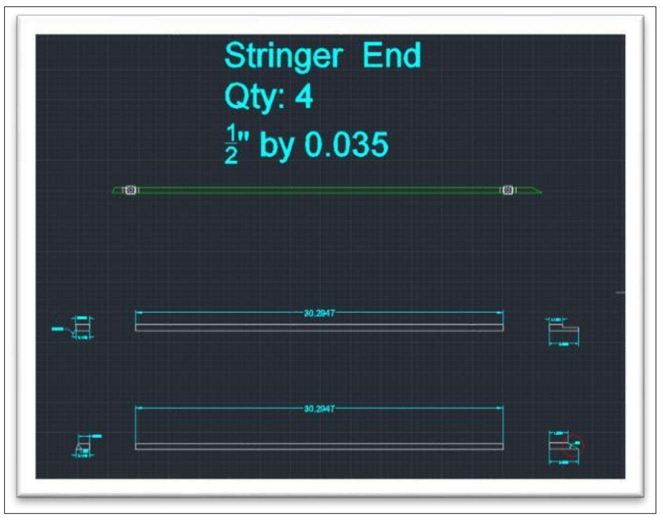

Figure 2.9 Stringer shop drawings.

Connections require far more drafting and machining to complete. Figure 2.10 shows the shop drawing for the T-slot prototype. Appendix C includes the entire set of shop drawings for the interrupted thread quick connect threads that were programmed and machined with CNC technology.

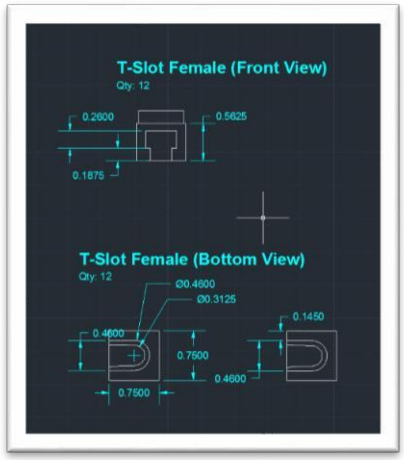

Figure 2.10 Prototype T-slot shop drawings

2.3 Bridge Manufacturing and Machining

The machining and manufacturing of the bridge is a slow and time-consuming venture that requires thousands of hours of shop training and highly specialized labor. Machining helps engineers develop a keen sense of advanced design practices that enhance constructability and technical communication between design engineers and contractors in the real world. Over a dozen student team members helped with cleaning the steel and rough cutting, milling, lathe work, and welding of the bridge. Altogether, over one thousand hours were spent in the manufacturing of the final bridge. All students participating in the steel bridge manufacturing phase had to complete Job Hazard Analysis (JHA) forms as well as specific training for each piece of equipment (lathe, mill, welder, plasma cutter, drill press, etc.) The steel for the bridge was ordered from Stock Car Steel and Aluminum in North Carolina. Stock Car Steel provides reliable shipping and handling and carries some of the rarest sizes of 4130 steel, steel found only with specialized NASCAR suppliers. The 4130 steel that we used for the bridge has excellent strength and precision compared with regular mild steel. Each piece of the bridge had to be milled to the precise length and angle (with a 1/1000 inch precision) requiring a high level of skill and attention. The steel had to be cleaned of oil and mill scales once it arrived, after which it had to be rough cut and milled to the correct length and angle. Connections take even more time. It is not uncommon for a connection to have over a dozen different steps of manufacturing.

Figure 2.11 Machining and manufacturing.

<u>2.4 Competition</u>

The Pacific Northwest (PNW) Regional Conference is usually held in mid-April each year. The 2015 competition was held at Idaho State University in Pocatello, Idaho. The stiffness and weight of the bridge is in large part dealt with through the design and manufacturing process. Since assembly time is a large part of a team’s total score, several days are commonly spent before the competition practicing bridge assembly. Connections have to be polished and filed to fit perfectly, and the order of assembly is improved through carefully analyzed optimization of the assembly.

The actual competition is organized as follows:

Registration

Practice assembly

Display setup (judges score bridges based on aesthetics)

Captains meeting (details are clarified before the competition get started

Timed assembly

Dimensional penalty check

Later loading (a 50 pound horizontal force is applied at the center of the bridge. Bridges deflecting more than an inch are disqualified)

Vertical loading (2500 pounds is applied to the bridge after which deflection is measured)

Chapter 3 Results and Discussion

3.1 Competition Results

The 2015 PNW Regional Steel Bridge Competition attracted thirteen schools to compete for the prestigious regional steel bridge first place (awarded to the team that designed the specified bridge with the lowest overall calculated dollar score). Idaho State University took third place with a calculated score of $44,080,000; Oregon State University took second place with a total score of $9,137,500; and UAF won first place by a large margin—a total score of $5,465,000.

Figure 3.1 Regional Champions!!!

Not only did the UAF steel bridge team win the overall competition, it won every single one of the six side categories. Thus, UAF had the lightest, stiffest, fastest, most aesthetically pleasing bridge, with the best construction economy and structural efficiency. UAF has competed really well in the past, but has never won all seven categories at the regional competition, so the 2015 regional competition is likely to be remembered for a long time. It is extremely hard to be the lightest bridge and still be the stiffest (strongest) bridge because of the nearly inverse linear relationship between stiffness and weight of steel structures (for example, as weight doubles, deflection is cut in half).

3.2 Lessons Learned

The lessons learned are many. It is evident that hard work contributes to good luck, but even more importantly, teamwork and a clearly defined common goal can overcome most all obstacles. Together, the UAF team tackled and overcame tremendously technical work under the conditions of sleep deprivation and heavy class loads. The team survived severe financial struggles, technical challenges, and tight deadlines. As a group, the students did so much more than simply design and build a competitive steel bridge. They completed hundreds of hours of community service and public speaking. They supported and in many ways were the core of UAF’s AGC and ASCE student organizations. Team members sacrificed time with loved ones and gave up personal time for a common goal: to design and manufacture the best bridge in the Pacific Northwest.

The 2015 steel bridge team succeeded in meeting a common goal, but actually achieved more than it set out to do. In the process, the team members gained important teamwork skills, a work ethic beyond what is required by many employers, and a personal drive for success that will benefit them no matter what industry or field of work they are in. Last but not least, team members formed enduring friendships. Success does, however, require many sacrifices. More than once, the goal and focus faded temporarily; but someone in the group always provided encouragement and renewed focus. In summary, here are some of the most important lessons learned:

- Each task will take at least three times longer than expected.

- Planning, planning, and more planning are required to keep a project on track and successful.
- Build a team and the product will build itself.
- Have fun and maintain good morale even when things are tough.
- Never let tasks on the critical path fall behind.
- Always have a backup plan.

3.3 Networking/Résumé Building

It was the journey of the team, not the product, which made this endeavor worthwhile. Not only did we build a bridge that would be particularly competitive at the national competition against some of the largest Ivy League engineering schools, but also we built a team that, in my opinion, could accomplish anything it sets its mind on. The steel bridge competition creates camaraderie and unforgettable memories, all while challenging and inspiring students and ultimately forming them into productive and innovative engineers of the future.

Supporting a competitive steel bridge team (materials and travel) requires an annual budget of $50,000. In meeting this budget, students gain fundraising and money-management skills. We spent countless hours interacting with businesses, professionals, and organizations around the community to raise the support necessary to ensure UAF’s legacy of elite national performance and continued success for present and future UAF College of Engineering and Mines students.

Chapter 4 Conclusion and Recommendations

The UAF steel bridge program offers students a great opportunity to get involved in an extracurricular activity associated with the civil engineering field. Participation gives students useful skills and experience, ultimately preparing them for a lifelong professional career as a civil engineer. UAF has a long history of strong performance at both the regional and national competitions—once again proven by strong performance at the 2015 regional competition at Idaho State University in Pocatello, Idaho. The UAF steel bridge team swept the competition by winning seven out of seven categories (for the first time in UAF history). UAF had the lightest, stiffest, fastest, most aesthetically pleasing bridge with the best construction economy and structural efficiency. That said, the success of the UAF steel bridge team should not be measured by trophies and titles won, but rather by the camaraderie and educational advantage that the members of the 2015 steel bridge team acquired through teamwork and focus on a common goal.

> *The potential professional development and growth that lie ahead of each member of the elite UAF steel bridge team is endless. I am thrilled to see each one of these extraordinary engineers spread across the nation to make the United States and the world a better place through sound and innovative engineering. Meanwhile, I hope that the strength of the UAF Steel Bridge program will continue to grow through sustained alumni and community support so that future students can receive the same exceptional opportunities that we received. Teamwork is at the base of the UAF Steel Bridge program. The transfer of knowledge between steel bridge generations makes us who we are. May the curiosity for learning and advancement never stagnate.*

Daniel Hjortstorp

Graduating Senior
B.S., Civil Engineering
UAF 2015 Steel Bridge Designer and Team Captain

References

Arrasmith, W. 2015. "Systems Engineering and Analysis of Electro-Optical and Infrared Systems." Retrieved from: https://books.google.com/books?id=Zo-9BwAAQBAJ&pg=PA653&lpg=PA653&dq=manufacturing+is+more+than+just+putting+parts+together.+It%E2%80%99s+coming+up+with+ideas,+testing+principles+and+perfecting+the+engineering,+as+well+as+the+final+assembly&source=bl&ots=Cxf_qLzDnS&sig=sXLYt619oZ6MdwG9HC_EKNMvI&hl=en&sa=X&ei=ewQ3Vdi1J5KhyASJ94GQDQ&ved=0CEUQ6AEwBw#v=onepage&q=manufacturing%20is%20more%20than%20just%20putting%20parts%20together.%20It%E2%80%99s%20coming%20up%20with%20ideas%2C%20testing%20principles%20and%20perfecting%20the%20engineering%2C%20as%20well%20as%20the%20final%20assembly&f=false.

2015 National Steel Bridge Student Competition. UMKC NSSBC 2015. Retrieved from https://www.aisc.org/content.aspx?id=780

Sources of Information Accessed During the Design Process

ASCE/AISC Student Steel Bridge Competition Guide. "2015. 2015 Competition Guide." Retrieved from: http://www.nssbc.info/History.htm

Bridge Design and Engineering. 2015. "Bridge Design and Engineering." Retrieved from: http://www.bridgeweb.com/Issue/Default.aspx

Bridge Engineering. 2015. "Wabash Bridge Competition." Retrieved from: http://www.phlf.org/downloads/education/Edu_WabashBridgeDesign.pdf

Flemming, D.J. 2015. "Bridge Engineering: Committee on General Structures." Retrieved from: http://onlinepubs.trb.org/onlinepubs/millennium/00013.pdf

Hibbeler, R.C. 2010. *Engineering Mechanics: Statistics and Mechanics.* 12th ed. New Jersey: Pearson Prentice Hall.

Hibbeler, R.C. 2012. *Structural Analysis*. 8th ed. New Jersey: Pearson Prentice Hall.

Ketchum, M. 2015. Mark Ketchum's Bridge Engineering Page. Retrieved from: http://www.ketchum.org/bridges.html

Kurtz, D.L. 2014. *Contemporary Marketing*. 16th ed. Mason: Cengage Learning.

Okyle, C. 2014. "10 Awesome Tips for Being a Better Leader." Retrieved from: http://www.entrepreneur.com/article/238747

Peurifoy, R.L. 2002. *Estimating Construction Costs*. 5th ed. New York: McGraw Hill.

RISA. 2015. "RISA 3-D: The Most Popular Structural Engineering Software in the U.S." Retrieved from: https://risa.com/p_risa3d.html

Segui, W.T. 2013. *Steel Design*. 5^{th} ed. Stamford, CT: Cengage Learning.

Stock Car Steel and Aluminum, Inc. 2015. “Best Online Source for Metals and Plastics.” Retrieved from: http://www.stockcarsteel.com/

Appendix A

A.1 Pictures

Figure A.1 Welding.

Figure A.2 Bridge assembly practice.

Figure A.3 Setting up each piece before the timed assembly at the competition.

Figure A.4 Applying the 2500 pound load with a pallet jack.

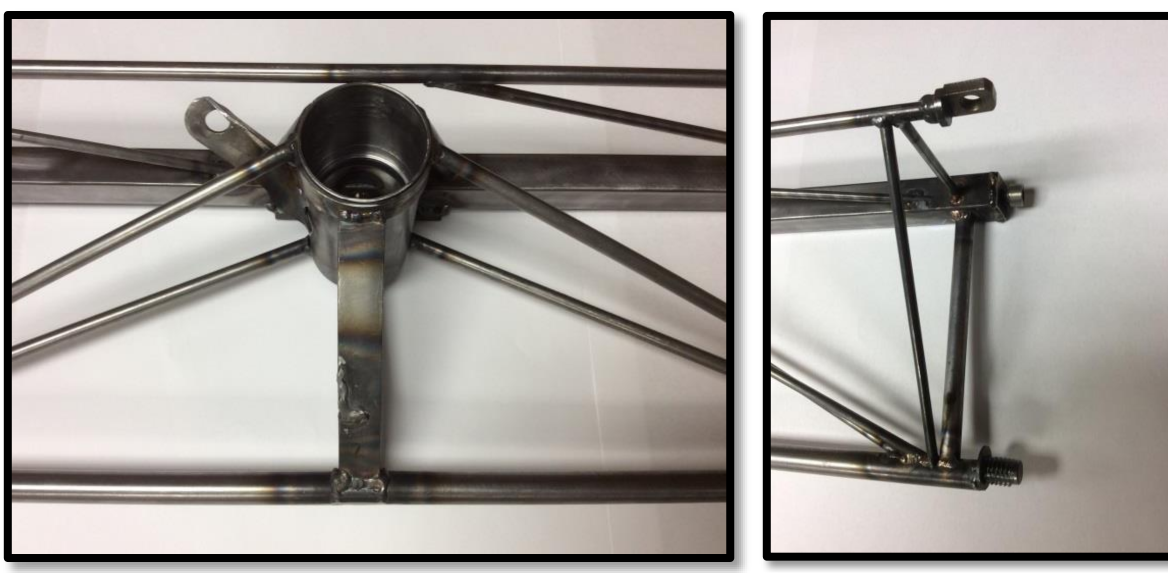

Figure A.5 Connections.

Figure A.6 Jig for cutting small 4130 round tube in the mill on the left. CNC'd interrupted threads on the right.

Figure A.7 Networking through the AGC Student Club.

A.2 Figures

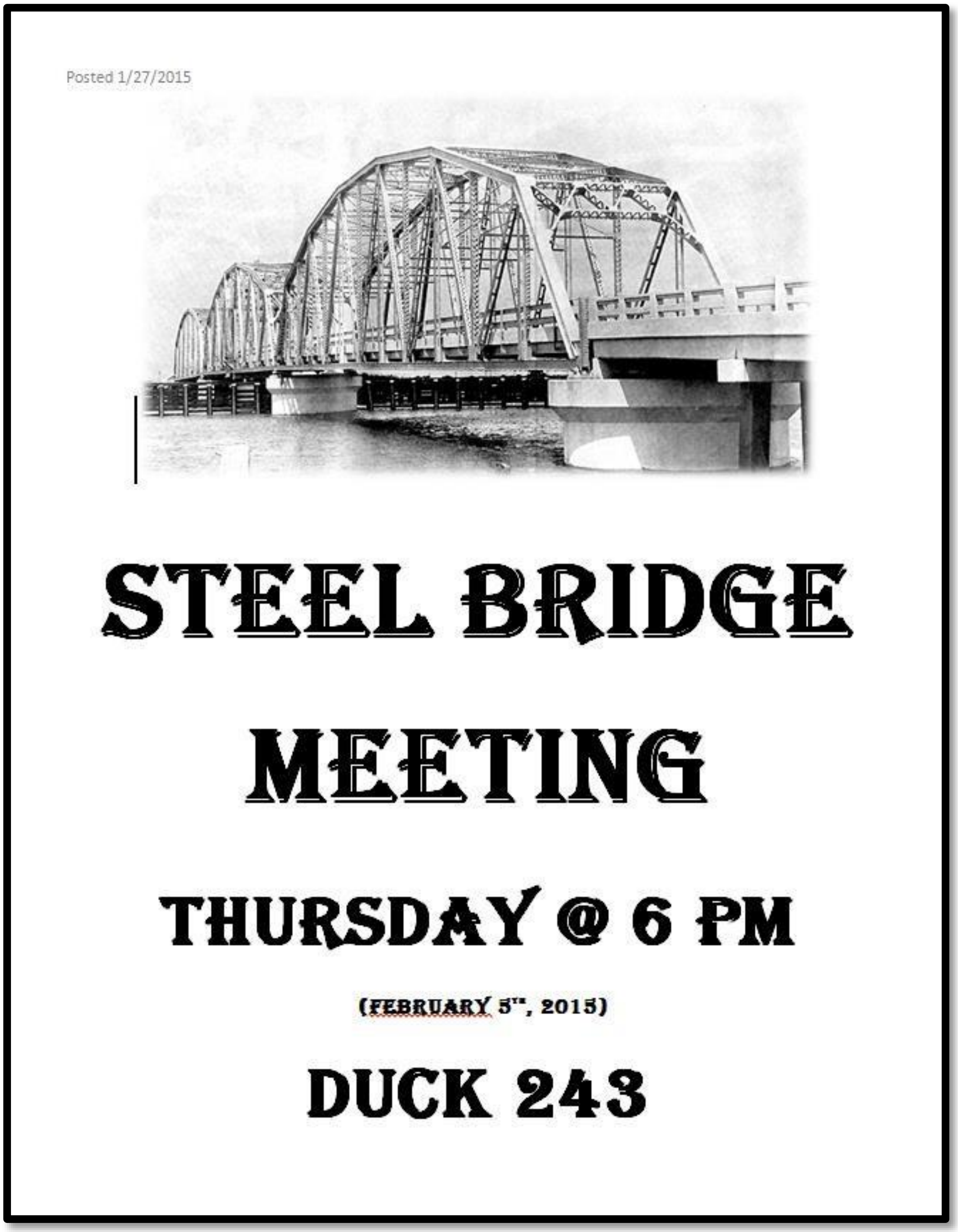

Figure A.8 Recruiting interest among students.

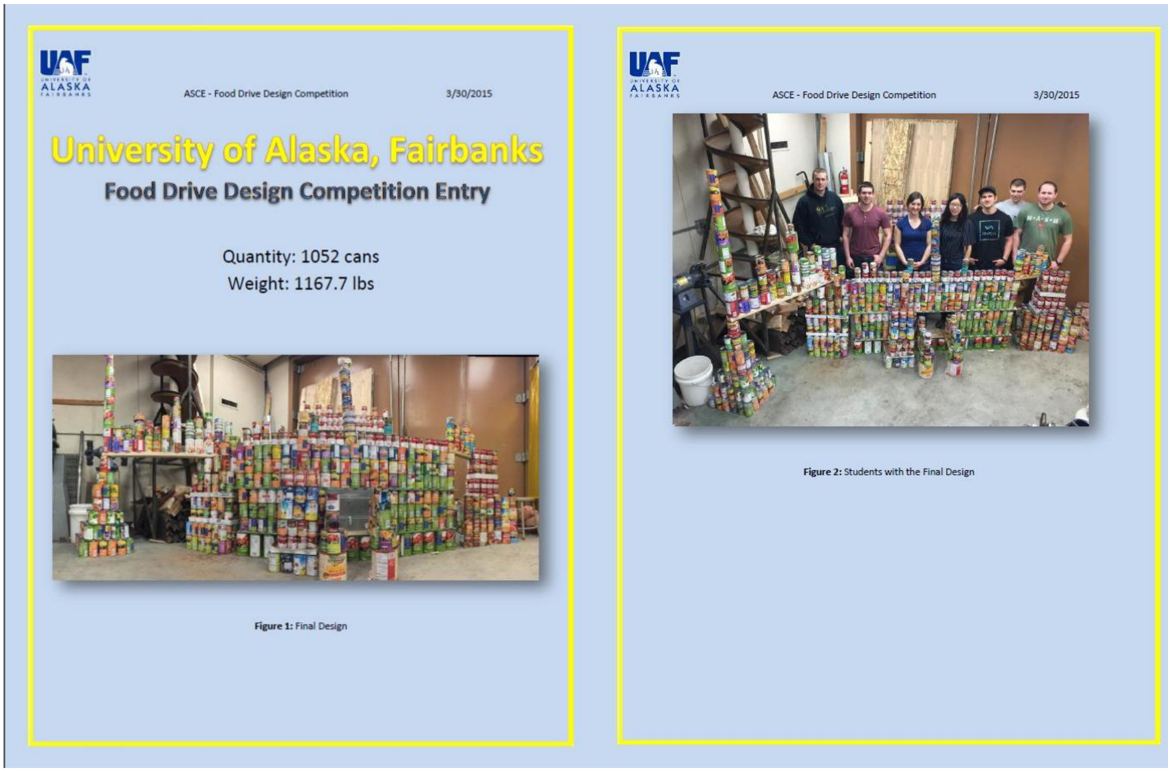

Figure A.9 Community service – results of a two day food drive effort.

"ADDRESSING THE NEEDS OF OUR STUDENTS AND PLANTING THE SEEDS FOR SUCCESS"

2014 FALL SEMESTER NEWSLETTER

Shaping tomorrow's leader's

The AGC Student Chapter Members were a large contributor to this year's winning team of the UAF Starvation Gulch.

After creating scaled construction, logistics, and safety plans, the giant pile of pallets took shape well within the small 4-hour window of time allowed. The "twin tower bridge" design concept required students to become resourceful, to work creatively within the rules, and to collect *thousands* of pallets after classes and homework.

Using some basic academic skills, hands-on ability, and competitive spirit, this group of students brought pride to the chapter, learned some valuable skills, and had some fun in the process. Also, the project attracted several Freshmen, and helped to recruit new members.

The bonfires have been a symbol of the passing of the torch of knowledge to new students at UAF since 1923.

Top: *Student Chapter members pose after completing the construction of a bonfire for Starvation Gulch. It was the only bonfire with a scaled drawing, and construction plan.*

Bottom: *Bonfire lights up the night, with the letters "UAF CEM" back-lit by flames.*

Helping Those in Need

Members from the UAF AGC Student Club had the opportunity to give back to the community by building bunk beds for a relocated homeless family. Students volunteered their Halloween Weekend to build and deliver these beds to a family of six kids in great need.

AGC members helping to build bunk beds.

Figure A.10 AGC newsletter created to gain student and community interest in what the AGC Student Club does (reaching out to the homeless, for example).

Figure A.11 Leadership certificate.

A.3 CAD Drawings

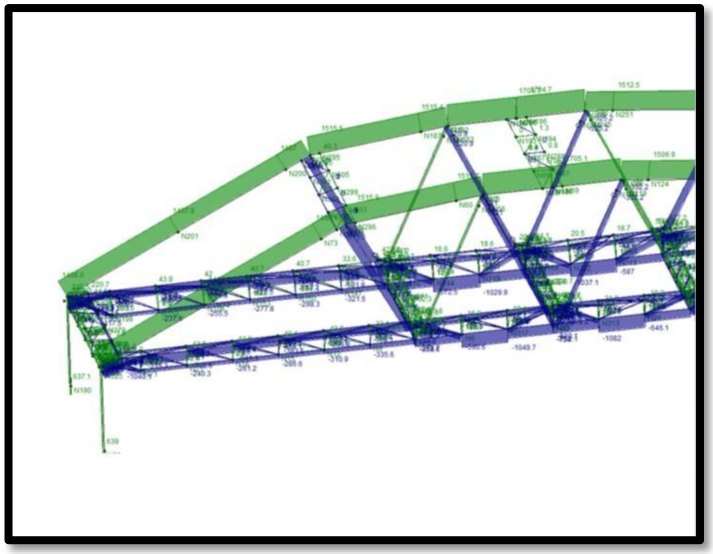

Figure A.12 Axial forces traveling through members in the final bridge design.

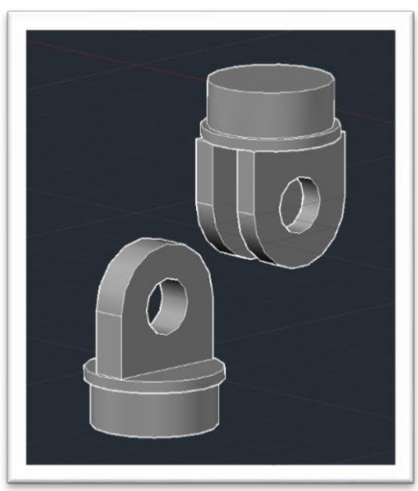

Figure A.13 CAD drawing of male-female connections.

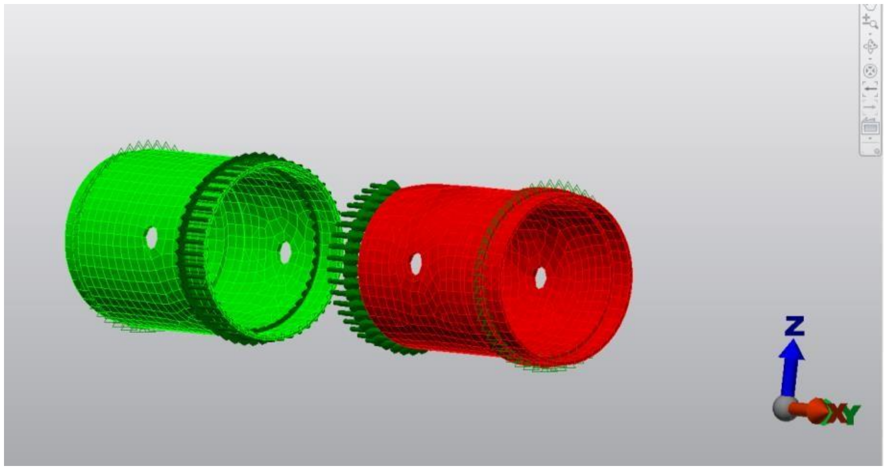

Figure A.14 Analyzing sleeve connections with Autodesk simulation.

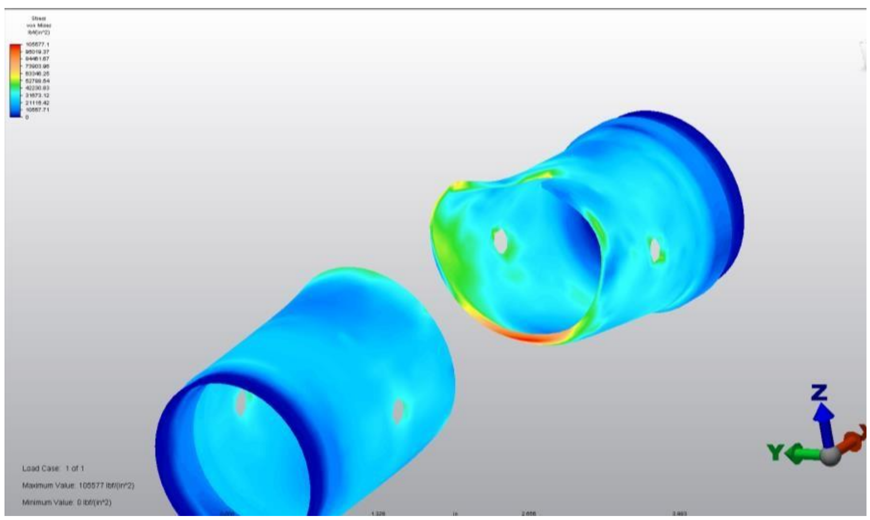

Figure A.15 Analyzing sleeve connections with Autodesk simulation.

A.4. Fundraising Material

UAF ASCE Student Chapter

306 Tanana Drive, 245 Duckering Building; P.O. Box 755900, Fairbanks, Alaska 99775-5900 ~ (907) 474-7241 ~ Fax (907) 474-6807
fycee@uaf.edu ~ www.uaf.edu/engineering/cee.htm

November 10th, 2014

Dear Supporter,

We are asking for your support of our dedicated engineering teams here at the University of Alaska Fairbanks. The annual ASCE/AISC Steel Bridge and Concrete Canoe Competitions creates the opportunity for UAF's College of Engineering and Mines (CEM) to consistently display its educational successes through some of the nation's most talented engineering students. Where larger schools provide the budgets and outside contractors do an excessive amount of work, UAF students proudly complete the entire process, from fundraising to design and in-house fabrication.

The UAF Steel Bridge Team has a long history of strong performance. We are nationally known for placing well in both the regional and national competition. We hope to continue this tradition of excellence with your support.

The UAF Concrete Canoe Team put in hundreds of hours last year constructing and designing an innovative floating concrete canoe to enter the competition for the first time in UAF history. This year's challenge of building a newly-designed, lightweight and structurally sound canoe will provide a strong foundation for current and future student growth.

Today, we ask for an early 2015 contribution to support our efforts. These competitions challenge and inspire the students, ultimately forming them into the productive and innovative engineers of the future. Maintaining a competitive Steel Bridge and Concrete Canoe Team requires a total annual budget of $60,000 (materials and travel). **With your support, we can ensure UAF's legacy of elite national performance and the prosperity of new and future UAF CEM students alike.** To learn more, please visit us on the web at cem.uaf.edu/news/2013-steel-bridge-regionals.

You may donate by mail (see envelope and card enclosed) or online at the following secure site: cem.uaf.edu/giving and follow the link to the **ASCE Student Competition Support Fund (Steel Bridge & Concrete Canoe)**. You will receive a receipt from the UA Foundation for your donation for tax purposes.

Thank you for your time, generosity and support of our growing program.

Sincerely,
The UAF Steel Bridge and Concrete Canoe Competition Program

Steel Bridge Project Manager *Concrete Canoe Project Manager*

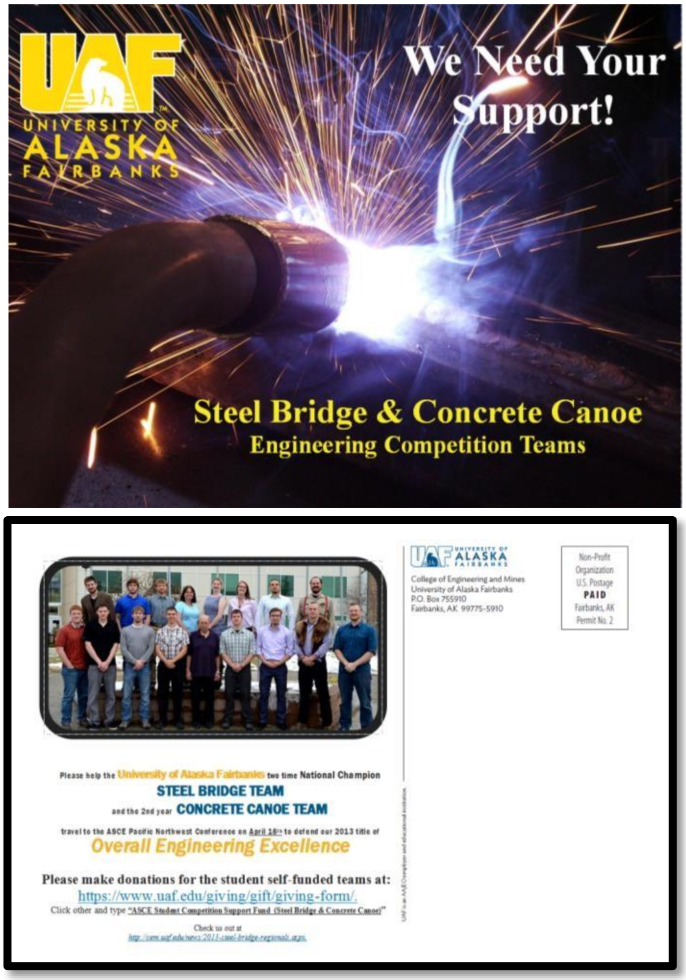

Figure A.16 Fundraising postcard.

Figure A.17 Fundraising postcard.

Figure A.18 Fundraising update.

March 23rd, 2015

Chancellor Brian Roger,

The Regional Steel Bridge and Concrete Canoe Competitions will take place during the ASCE Student Conference at the Idaho State University between April 16th and April 18th. We are asking for your help to support our dedicated engineering teams as they travel to the competitions were they will represent the University of Alaska (UAF) in the Steel Bridge Competition, Concrete Canoe Competition, Environmental Challenge, Transportation Challenge, and Technical Paper Competition.

Travel dates will be April 15th– April 19th. Flights to Pocatello, Idaho currently cost $1,041.00 but are certain to increase as the travel dates quickly approach. We have already booked hotels in Pocatello at the Rodeway Inn between April 15th and April 19th for students and faculty traveling and have two minivans quoted at $611 per vehicle. In addition, we will need to cover the expenses of transporting both the bridge and canoe to the competitions. The bridge may be shipped as luggage on the airplane and the canoe will be trucked to a logistical hub in the states. Rental of a U-Haul to transport the canoe from Seattle or Tacoma to Pocatello may cost up to $2,000 once mileage charges have been added.

The UAF Steel Bridge Team has a long history of strong performance. We are nationally known for placing well in both the regional and national competition. The UAF Concrete Canoe Team dedicated hundreds of hours last year constructing and designing an innovative floating concrete canoe to enter the competition for the first time in UAF's history. This year's challenge of building a competitive lightweight and structurally sound canoe will provide a strong foundation for current and future student growth. These competitions challenge and inspire the students, ultimately forming them into the productive and innovative engineers of the future.

Due to Alaska's location, we have large travel expenses compared to other universities in the nation. Our students have spent countless hours fundraising and promoting our efforts to the community to raise the money to purchase materials and supplies for construction of these projects.

We are asking for your financial support covering the airfare for four ($1,041 * 4 = $4,164) of the students traveling to the Regional ASCE Student Conference where will display UAF's College of Engineering and Mines (CEM) educational practices through some of the nation's most talented engineering students at the Steel Bridge, Concrete Canoe, and many other academically challenging competitions.

Thank you for supporting our academic growth and learning.

Sincerely,
Daniel Hjortstorp
Steel Bridge Team Captain
dphjortstorp@alaska.edu
(907) 320 6078

UAF Steel Bridge Team

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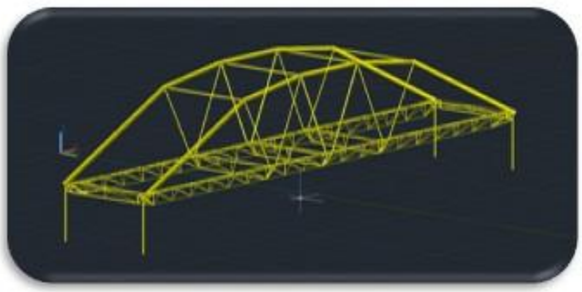
February 6th, 2015

Dear Jim,

We are excited to yet again gather forces for another ASCE/AISC Steel Bridge Competition. The 2015 Steel Bridge rules are quite similar to last year's rules except for a few distinct changes. The scoring is almost identical but the overall span of this year's bridge has increased to 18.5 feet compared to last year when we only had to span 17 feet. Furthermore, certain penalties have increased dramatically making it crucial to avoid mistakes during the timed assembly at the competition.

This year's competition has attracted a lot of interest, especially among younger students, making the outlook for our 2015 UAF Steel Bridge Team bright. The team has met on a regular basis since the fall to collaborate on design and discuss building methods that conform to the new rules. The bridge features a slender space truss for the bottom chord combined with a stout upper chord that will help avoid unexpected behavior under compression.



2015 Steel Bridge Design

The bridge will be constructed out of 4130 round tube except for the decking surface and the legs that will be made out of box tube. We are currently developing shop drawings, checking the RISA computer analysis with hand calculations, and detailing connections while waiting on steel to arrive. The regulations for connections once again make it possible to apply engineering knowledge and ingenuity into the connection-design (unlike the last three years when the regulations for connections dampened creativity). We are currently designing and brainstorming different connections in order to carry on the long tradition of excellent connections that UAF is nationally known for. We currently expect to start machining pieces for the bridge later this week with some of the supply that we already have in stock.

We really appreciate your support and devotion to ensure a bright future for the UAF Steel Bridge program. The Steel Bridge Competition challenge and inspire students, ultimately forming them into productive and innovative engineers of the future. Your donations help us ensure that UAF's legacy of elite national performance endures and that the prosperity of new UAF CEM students will continue long into the future through the Steel Bridge Program.

Sincerely,

The 2015 Steel Bridge Team