NORTHERN ARIZONA UNIVERSITY

100% Design Report

2015 ASCE Steel Bridge

Trussanasaurous Rex

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1 Project Description

The objective of this project was to design, analyze, fabricate, and construct a 1:10 scale model of a steel bridge. The model bridge was the Northern Arizona University (NAU) – American Society of Civil Engineers (ASCE) Student Chapter entry in a competition at the 2015 Pacific Southwest Conference (PSWC). The event is sponsored by ASCE and the American Institute of Steel Construction (AISC). AISC and ASCE provide regulations and specifications for the competition. At the conference, bridges are judged on construction speed, aesthetics, and strength. The team that performs the best overall will be awarded a contract for the full-scale project. Meetings were held with the client and the technical advisor for this project was identified and meetings with these parties were held to assess expectations. Both parties set a goal for the team to qualify for the competition and place as highly as possible.

1.1 Background

From the fictional back-story provided in this year's competition rules, the President of Kuprica requested construction of a bridge to increase commerce in the fictional country. The bridge will span over the Nogo River to connect the capital city, H'sogo, to surrounding villages. The project will be funded by the Sonarpin Foundation, which recommends that the bridge be made of steel. This is because of the material's durability, ease of maintenance, and ability to be prefabricated, allowing speedy construction. The bridge cannot have piers in the riverbed or immediate surrounding area due to highly organic soil. Only two footings, one on either side of the river are available for use. The bridge must provide clearance over the river, with enough room for boats to pass under during the wet season. A temporary causeway will be placed to help with construction.

The Sonarpin Foundation will award a contract to the company with the most effective 1:10 scale bridge model. The bridge model is assembled during a timed construction period as part of the ASCE Steel Bridge Competition in order to determine constructability. The model is loaded both laterally and vertically to find the aggregate deflection and is judged against other models. Any model that does not follow the rules was rejected or penalized. The best bridge model was awarded a contract with the country of Kuprica.

1.2 Stakeholders

Since this project is for the ASCE and AISC Student Steel Bridge Competition, the stakeholders for this project are divided into two primary groups. The first group are the people of Kuprica, for whom the model bridge is being built. The main client in this stakeholder group is the President of Kuprica, who has requested a bridge be constructed over a local river to increase commerce within the country. The model bridge should demonstrate stability, strength, serviceability, and ease of construction, allowing Kuprica to choose the bridge that will best meet their needs. The chosen bridge will be constructed; thus, all of the citizens are stakeholders in this project.

The second group of stakeholders is people affiliated with NAU: the client Mark Lamer, Northern Arizona University, and the NAU-ASCE Student Chapter. Due to the competitive nature of the steel bridge project, the team is representing these stakeholders.

1.3 Existing Conditions

Every year, AISC and ASCE collaborate to hold a competition for civil and environmental engineering students. NAU has competed in this competition in previous years; however, each year the rules are changed so that a bridge design cannot be reused. Therefore, there are no existing conditions for this project. Currently there is not a bridge in the country of Kuprica. A raised river crossing would be an improvement to the current conditions.

1.4 Technical Needs

The 1:10 scale bridge was designed within the parameters set forth by the Sonarpin Foundation. Foremost, the bridge was required to be constructed with steel only. The bridge dimensions must meet the building envelope provided in Figure A1 and Figure A2 in Appendix A. Each bridge member must be at most 3’ by 6” by 4”. The completed model was judged on display, construction speed, weight, stiffness, construction economy, and structural efficiency. Aesthetics are based on its balance, proportion, elegance, and finish.

Construction economy (Cc) assesses the design's cost and is based on the following formula [1]:

Equation 1:

$$Cc = \text{Total Time (minutes)} \times \text{Number of Builders (persons)} \times 50{,}000\ (\$/\text{person-minute}) + \text{Load Test Penalties } (\$)$$

Construction speed is the time it takes to construct the bridge model. Time is added for various penalties, such as dropping tools. The time to construct the bridge must be less than 45 minutes, but any time over 30 minutes will result in a construction time score of 180 minutes. Construction is halted at the 45-minute mark regardless of build completion.

The Structural Efficiency (Cs) is used to judge the model's structural design, and is calculated using the formulas based on the weight of the model [2]:

Equation 2: (weight < 400 lbs)

$$Cs = \text{Total Weight (Pounds)} \times 20{,}000\ (\$/\text{Pound}) + \text{Aggregate Deflection (Inches)} \times 1{,}000{,}000\ (\$/\text{Inch}) + \text{Load Test Penalties } (\$)$$

Equation 3: (weight > 400 lbs)

$$Cs = [\text{Total Weight (Pounds)}]^2 \times 50\ (\$/\text{Pound2}) + \text{Aggregate deflection (Inches)} \times 1{,}000{,}000\ (\$/\text{Inch}) + \text{Load test penalties } (\$)$$

Weight is a combination of actual weight of the bridge and the weight incurred through penalties. The loading decking is not incorporated into the weight of the bridge since it will be uniform for all bridges entered. The overall performance of the bridge is judged on a combination of construction economy and structural efficiency. A lower score indicates a more effective design.

The bridge must meet the following requirements:

- All bolts must be 3" or shorter
- Nuts must be hexagonal in shape
- Each bolt and nut location must be tight so that the bolt and nut touch the member they are fastening

- Each nut must be fully engaged
- The bridge may be at most five feet tall, five feet wide, and at least 18'- 6" long (Figures A1 and A2 in Appendix A).
- There must be at least a 1'-6" clearance over the river (Figures A1 and A2 in Appendix A)
- A minimum of 3.5" clearance over the surrounding ground must be maintained
- There must be two decking support surfaces that run parallel along the length of the bridge with no more than 2'-7" above the ground or river
- The supports for the decking must be at least 2'-6" wide and at most 3'-2" wide (Figure A1 in Appendix A)
- There must be a path of travel on top of the deck supports that measures at minimum 3'-7" wide by 1'-6" tall for a hypothetical vehicle, (Figure A1 in Appendix A)

1.5 Potential Challenges

The ASCE PSWC was held in April 2015 at the University of Arizona in Tucson, AZ. The team had to complete design and fabrication by this time. Completing all necessary tasks for construction in the limited time was a challenge as a team. To combat this time constraint, the team utilized accelerated bridge construction methods and followed a strict schedule. By planning, the team reduced the effect that the time constraint had on the overall project.

An additional challenge for this project was the highly organic soil. The organic soil, makes the use of temporary piers, false work, or barges impractical. Because of the tropical climate and extreme monsoons, the building season is short; meaning the bridge must be constructed quickly while remaining durable. Another challenge stems from the need to cart all materials in by ox. The materials must be light and compact. Size and weight constraints were a consideration for the model design and limited the maximum size of the members.

2 Scope and Tasks

The scope of services for which the 2015 NAU ASCE Steel Bridge team was responsible for are listed below. This project was divided into five main tasks which are research, design/analysis, fabrication/construction, ASCE conference, and project management.

2.1 Research

2.1.1 Truss Design – Each team member researched different types of trusses. The team members discussed the strengths and weaknesses of the designs to determined trusses that best fit the problem outlined in the competition rules. The designs were then ranked in a decision matrix. The selected truss design was researched and analyzed in detail, considering factors such as constructability, strength, and aesthetic appeal.

2.1.2 Rules – The ASCE Steel Bridge competition rules were read and discussed by all team members. Each member understood the competition guidelines for the bridge. The bridge envelope was redrawn so that the members understood the maximum and minimum dimensions. All rules were followed in design and construction.

2.1.3 Clarifications – When the team did not understand a rule, a clarification request was submitted to the ASCE competition website. Periodically, the team looked at the clarifications requested by other groups.

2.1.4 Connection Types – Different connections were researched to determine the most efficient connection type for of the bridge. The connections had to withstand the different loading patterns denoted by the rules and had to be easy to connect during construction.

2.1.5 Construction Methods – The team researched and brainstormed different ways the bridge could be constructed given the rules. These different construction techniques were tested on small and full-size scales to determine which techniques will be easiest and quickest.

2.2 Design/Analysis

2.2.1 Truss Design Selection - After ranking the initial geometric designs with the decision matrix, the top designs were discussed further. The team consulted the faculty advisor and additional structural professors for professional input on the truss design.

2.2.2 Determining Dimensions – After deciding on a truss design, a team member drafted an AutoCAD drawing of the truss. From the drawing, the team determined the structural member dimensions needed to stay within the building envelope while maximizing strength.

2.2.3 RISA Analysis – The final truss design was analyzed with RISA, a structural analysis software program. The RISA computer-based analysis provided the necessary steel specifications for each member, such as dimensions and cross-sectional area.

2.2.4 Steel Specifications- The team determined the steel gage based on the dimensions and RISA analysis. The steel was designed to withstand the load cases set forth in the rule set.

2.2.5 Final Design Drafting – The final design was drawn with the determined dimensions and steel type. The plans were submitted to the client and technical advisor for review. After the design was finalized, a set of shop drawings were provided for fabrication of individual structural members.

2.3 Construction/Fabrication

2.3.1 Fabrication- The team was responsible for all fabrication of the bridge. If the team has been unable to satisfactorily complete fabrication then an outside supplier would have been identified. The team began fabrication with adequate time for completion prior to ASCE conference in April.

2.3.2 Shop drawings- The team provided shop drawings for fabrication. The shop drawings were reviewed and approved by the client and technical advisor. The team procured all raw materials for fabrication.

2.3.3 Post fabrication- After fabrication, the team was responsible for construction and inspection of the completed bridge to ensure everything had been constructed appropriately.

2.3.4 Construction- The team practiced construction methods on the fully fabricated bridge components. This served as practice for conference. The team was responsible for practicing their construction so that it could be completed within the 45-minute time constraint.

2.4 ASCE Conference

2.4.1 Conference Activities – The team was expected to compete at the PSWC ASCE Student Conference in the Steel Bridge Competition, held at the University of Arizona in Tucson, Arizona. All team members were expected to attend and participate. Only builders, up to six team members specified for construction, could work on the bridge during the specified competition time.

2.4.2 Display Day –During the conference, a display of the bridge was required. At that point, the bridge had to be complete and no further changes could be made, per the ASCE 2015 Steel bridge regulations.

2.4.3 Travel and Lodging – Travel, lodging, conference fees, and meals during the Steel Bridge Competition were not within the scope. The funding for these items was not provided by the steel bridge team.

2.4.4 Display Board – As part of the competition, a display board was required. The mentees, underclassmen assisting with the project, were responsible for the display completion. In the event that the display board was not completed by the mentees, responsibility for completion would have fell on the steel bridge team members. The display board was to be completed by conference.

2.4.5 Tools – The steel bridge team was responsible for procuring all tools needed to complete the bridge construction during the competition. In addition to competition tools, the team was responsible for any tools that may be needed for last-minute repairs. If the bridge broke pre-construction due to actions by a team member, the team was responsible for repairing the damages. The team was not responsible for transportation of tools or materials to the competition site; that will be handled by the NAU ASCE student chapter.

2.4.6 Unexpected Circumstances - If an unforeseen circumstance had arisen and the ASCE PSWC competition was canceled, the team was no longer expected to travel to Tucson, AZ or build the bridge at that location. Further decisions on how to proceed would have needed to be determined at that point.

2.5 Project Management

2.5.1 Project Schedule – The team has generated a schedule with all of the project milestones, tasks, subtasks, and their respective dates (Appendix C). The team was expected to follow this schedule. Should the team have missed a due date; modifications to the schedule would have been made to correct the timeline. The team was required to complete the bridge by the time of the conference. The team was responsible for keeping the client informed about the schedule.

2.5.2 30% Drawings – The 30% bridge design plans included a general schematic plan of the bridge and basic dimensions. The team provided a copy of the 30% design plans to the client for review.

2.5.3 60% Drawings – The 60% bridge design plans included a detailed schematic of the bridge and all dimensions. In addition, preliminary analysis of the design's performance under loading was included. The team provided copies of the 60% design plans to the client for his/her review.

2.5.4 90% Drawings – The 90% bridge design plans included all of the information provided in the 60% plans with the addition of the member cross-sectional area, connection specifics, and the grade of steel. All quantities were included in the 90% plans. All analysis of the design's performance was conducted. The team used the 90% plans to create shop drawings for fabrication. The team provided a copy of the 90% design plans to the client for his/her review.

2.5.5 Material Procurement – The team was responsible for establishing sponsorships for the fabrication and construction of the bridge. This included steel, nuts, bolts, paint, hand-tools, and other miscellaneous tools needed for construction. The team was also responsible for establishing a method of transporting the materials from the vendors to the fabrication site.

2.5.6 Staffing – The team established internal roles and respective tasks. The roles were Design Engineer, Safety Engineer, Scheduling Engineer, Materials Engineer, and Project Manager. The team was responsible for verifying that all tasks under each role were fulfilled. In addition to the roles, four mentees shadowed and assisted the team with the project. The team was responsible for selecting mentees, arranging meeting times with the mentees, and assigning tasks for the mentees.

2.5.7 Conflict Resolution – The team was responsible for handling any conflicts according to the Team Charter. The charter required team members to handle the conflict internally at two levels. If the conflict could not be resolved internally, the team would have escalated the conflict to an instructor.

3 Design Alternatives

The team individually researched truss designs. A meeting was then held to discuss the design options brought forth by each member. Six different truss designs were analyzed: an arch with decking along the middle of the bridge, a camelback truss, an integrated truss/arch, a Warren truss, a bowstring truss, and a beam style bridge with an arch support. The options are depicted in Figure B1 in Appendix B. The team then determined the criteria to judge the different designs. The criteria selected include strength, lightness, aesthetics, constructability, and ease of fabrication.

- Strength (S): Overall strength of the bridge and its ability to carry the required weight. Each design was assigned a strength rating of five since any design will be able to be adjusted to carry the weight. This criterion was weighted 25% of the score since it is the goal of the competition.
- Lightness (L): This factor is the predicted lightness of the design. Considerations in this criterion included the potential number of members and connections. Lightness is 30% of the overall score since the bridge's performance in the competition is highly dependent on the weight.
- Aesthetics (A): Aesthetics was based off the team's opinion of uniqueness of design, as well as the elegance and balance of the design as required by the competition rules. Aesthetics is weighted at 10% of the score since it is subjective and not a large portion of the bridge's score in conference.

- Constructability (C): Constructability is the team’s prediction of how easy the bridge will be to construct during competition considering the number of members and connection points. This is a large portion of the conference score and that is reflected in the decision matrix weight of 20%.
- Ease of Fabrication (F): This is the simplicity and amount of fabrication that the team suspects will be required for the design. 15% of the design score went to this factor since this determines the amount of time to make the bridge and potential to have a fabrication error.

These five criteria were scored and weighted on a scale 1-5 with 1 being the lowest score/poorer option and 5 being the highest score/best option. All values entered into the decision matrix were discussed among the team members and agreed upon.

The decision matrix can be seen in Table B1of Appendix B. The two highest-ranking truss designs were determined to be the camelback and the Warren. The strong points of these two designs were combined to create the final design. The combined design was fully analyzed.

4 Testing and Analysis

The structural analysis software RISA was used to analyze and design the bridge. The initial truss design was drawn using AutoCAD and then imported into RISA. All of the members were specified as being one size 1” hot rolled steel pipe. The design was analyzed using a pinned end and a roller end with each possible load combinations applied as point loads at the loading locations provided. The design was then adjusted to determine what type of additional supports above and below the legs of the truss were needed to reduce deflection. After the truss design was finalized, with cross bracing for the legs of the truss, the design was tested within RISA to determine the optimal member sizes. Only two member sizes are used in the final truss design, not including the angle bars used for cross bracing on the top of the bridge, to simplify fabrication. RISA 3D was explored for member sizing but after meeting with the technical advisor it was deemed overcomplicated and not necessary.

4.1 Member Sizing

To find the appropriate member sizes, dimensions, provided by Agate Inc. were manually entered into RISA. The members were changed from the default setting to a larger size of 1-1/2”. The deflection was less than 1” but the weight of the bridge was too great so the members were downsized. The inner truss members were changed to the next smallest size, 1”. The weight of the bridge was still too great. The outer members were also changed to 1” and the inner members were changed to 3/4”. The deflection of the bridge remained less than the determined minimum; however, the weight was too large so the sizes were again decreased. The outer members were changed to 3/4” and the inner were changed to 1/2”. The deflection did not change greatly so the members were again decreased in size to determine how small the members could be to decrease the weight. The outer members were changed to 1/2" and the inner to 1/4”. The deflection of that iteration was greater than the minimum allowable so the members were changed to the previous iteration. These sizes were used for the final member sizes of the truss.

Table 1: Deflection Testing Results

Member Sizing	Envelope Loading		
	Member Deflection (in)	**Joint Deflection (in)**	**Kick Out (in)**
exterior (1”-40)_ interior (1/2”-40)	0.366	0.056	
exterior (1-1/4”-40)_ interior (3/4”-40)	0.175	0.039	
exterior (3/4”-40)_interior (3/8-40)	0.825	0.087	
exterior (3/4”-40)_interior (1/2”-40)	0.766	0.099	0.081
All 3/4”-40	0.762	0.091	0.081

A final design of the cross bracing of the top and bottom of the bridge was also uploaded from an AutoCAD file to RISA to determine if the cross bracing is sufficient to withstand the 50 lbs of horizontal force the bridge will be subjected to. The outer members of the top and bottom sections were set to 3/4” and the inner members, excluding the angle bars on the top, were set as 1/2” members. The top angle bars were designed as angle bar that has the same thickness as the gusset plates. The gusset plates will be used for connections and will be discussed later. The top and bottom members meet the deflection requirements with a 50 lb load added to the middle of the sections

4.2 Gusset Specification

Bolt size for the bridge was selected to be 5/16” with a 1-1/2” thread length. The bolt size was selected based on the ease of handling the bolts by the team members since during the competition, the team will be penalized for any dropped bolts. This thread length was selected based on the gusset plate thickness (5/16”) and the larger of the two pipe sizes (3/4”). The gusset and pipe total to a thickness of 1-1/16”, which is within the 1-1/2” thread length provided.

Once bolt sizing was complete, the gussets were designed. These were designed using the bolt edge distances per Figure 1.

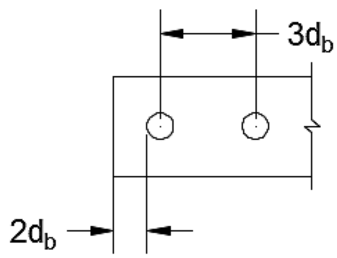

Figure 1: Bolt Edge Distances

These distances are based on American Institute Steel Construction’s (AISC) Specifications J3.3 and Table J.3.4. Specification J3.3 indicates that the minimum distance(s) between the centers of bolt holes is preferred to be three times the diameter of the bolt [2]. Table J.3.4 is as follows:

Table 2: AISC Minimum Edge Distance [2]

Bolt Diameter, in.	Minimum Edge Distance
1/2	3/4
5/8	7/8
3/4	1
7/8	1 1/8
1	1 1/4
1 1/8	1 1/2
1 1/4	1 5/8
Over 1 1/4	1 1/4 × *d*

Based on Table 2 above, a minimum edge distance of approximately one and half times the bolt diameter is required. To provide a margin of error, this was rounded up to twice the bolts diameter. Based on the AISC Specifications, the bolts edge distances used are 15/16" and 5/8".

In order to determine the proper plate thickness, bearing calculations were completed. From the RISA analysis, the maximum tension in any member was found to be 2,100 pounds. The plate strength was assumed to be 65,000 psi and the bolt strength was assumed to be 150,000 psi, both typical values. This information, as well as the bolt diameter and an assumed plate thickness, was used to calculate the bearing stress. With an assumed plate thickness of 5/16", the value ultimately decided on, the bearing stress was calculated to be 10,750 psi.

The calculated bearing stress was then compared to the connection strength, or ϕR_n [2]. ϕ, the factor of safety, was set to 0.75, a typical value for single bolts. R_n is equal to 2.4 times the maximum tension times the bolt cross sectional area. The factor 2.4 allows for minimal deflection. ϕR_n was calculated to be 11,426 psi. Since the connection strength is larger than the bearing stress it will experience, the connection is appropriately designed.

5 Final Design

The final design for the bridge was created by combining the strong points of the two highest scoring designs from the decision matrix. A Warren Truss was determined to be a simple design that would have minimal members and connection points. This was placed in a trapezoidal shape with elevated flat decking. Included in this design, is interior members that connect to the decking to the leg of the bridge. This increased stability of the bridge, and reduce potential deflection. The 100% design can be found following this report detailing all connections, members, dimensions, etc. According to the RISA analysis, the maximum deflection that that should be seen in any member is 0.766", which is well in the 3" allowable deflection.

5.1 Results

Upon receiving the gusset connections from the steel provider, the team discovered that the incorrect bolt hole sizes was used. The team checked that the plate calculations for the plates received were still appropriate. A 10mm size bolt was determined to be sufficient and the incorrect plates were deemed usable by the team. Additionally, during the fabrication of the bridge, some of the members were not completely straight due to the equipment that was available for use.

At conference, the bridge underwent a time build. The team used accelerated bridge construction method. The team was able to build the bridge in 42.5 minute with a total of 15 drops resulting in a 15-second time penalty for each. This is average for a timed build competition. Additionally, three larger time penalties were applied for bolts not being fully engaged to the nut. After the timed build, the bridge was inspected for dimensional violations. Due to the team fabricating the bridge themselves, a small dimensional violation was discovered in the rails of the bridge. This resulted in a 50 lb. weight penalty.

The bridge was the loaded by the team. During lateral loading, the team applied the 50 lbs. required and saw a deflection of zero. The bridge was then vertically loaded to Load Case 5. The bridge was able to hold 2,100 pounds before failure. Bridge failure was not due to design, but to the team's fabrication. The top chords were not completely straight and during loading, a moment incurred in the top chord increased. This resulted in one of the center joints moving in the lateral direction approximately 6 inches. This was cause for immediate disqualification of the bridge. Even though the bridge technically failed during loading, the rest of the bridge is still in perfect condition. Minimal repairs would be required to fix the bridge. Prior to failure, the bridge experienced minimal deflection as expected.

6 Project Summary

The steel bridge project was scheduled and the cost of services evaluated.

6.1 Scheduling

A Gantt Chart was created for the project. Milestones, tasks, and subtasks were denoted. Milestones are depicted as diamonds and are paired with their specific date. All tasks and milestones are indicated, as well as dependencies, start dates, and end dates.

The original Gantt Chart, created at that start of the project, is shown in Figure C1 in Appendix C. An updated version is shown in Figure C2 in Appendix C. The only difference between the two is the materials task, under which ordering materials and receiving materials both start and end later than originally planned. The change in schedule does not affect the following tasks, since the materials will still be received with adequate time to complete fabrication.

6.2 Cost of Engineering Services

Based on the scope of the Steel Bridge Project, a staffing and cost estimate was assembled.

A fee schedule, including all team members, was assembled, and is shown below to serve as the basis for the cost of services rendered for the duration of this project.

Personnel Classification	Billing Rate ($/hr)
Project Manager …………………………………………………...	78.00
Conference Captain/Safety Engineer…………………………………	73.00
Scheduling Engineer………………………………………………….	65.00
Design Engineer …………………………………………………...	70.00
Intern …………………………………………………………….....	14.00

Engineering services for this project are divided into five main tasks: initial design, design finalization, materials, fabrication, and the Pacific Southwest Conference. A breakdown of the anticipated hours for each task is provided in Table 3. The difference in project cost from the original proposal and the current status of the project is approximately $8,000 less coming in around $65,000. In the original proposal, the team anticipated the teammates spending 58 hours on design finalization; however, only 52 hours were spent on this task. The majority of the cost difference is due to the fabrication costs that were removed. The team will be fabricating the bridge internally; therefore, the original subcontract cost of $2000 was eliminated. Additionally, material costs were reduced due to an overestimate of the cost of steel. The team planned to spend $700 on the steel for all members; however, the cost was only $325.

Table 3 is a summary of all costs associated with completion of the project. These costs include all personnel costs, travel expenses, subcontracts, and materials. These values are subject to change. The anticipated cost for this project is $89,800, with a majority of the cost allocated towards personnel costs. Information regarding the calculation of billable rates for all personnel is located in Table D1 in the appendix.

Table 3: Cost of Engineering Services for 2015 Steel Bridge project

	Original Estimate			Actual Value		
1.0 Personnel						
Classification	***Hours***	***Rate [$/hr]***	***Cost [$]***	***Hours***	***Rate [$/hr]***	***Cost [$]***
Project Manager	243	78	18954.00	287	78	22386.00
Conference Captain/Safety Engineer	230	73	16790.00	311	73	22703.00
Scheduling Engineer	233	65	15145.00	298	65	19370.00
Design Engineer	230	70	16100.00	275	70	19250.00
Intern 1	49	14	686.00	75	14	1050.00
Intern 2	49	14	686.00	75	14	1050.00
Intern 3	79	14	1106.00	75	14	1050.00
Intern 4	79	14	1106.00	75	14	1050.00
Subtotal	*1192*		*70573.00*	*1471*		*87909.00*
2.0 Travel						
Classification	***Distance (Miles)***	***Rate [$/mi]***	***Cost [$]***	***Distance (Miles)***	***Rate [$/mi]***	***Cost [$]***
Steel Transport	310	0.50	155.00	310	0.50	155.00
Nuts and Bolts Transport	5	0.50	2.50	5	0.50	2.50
Fabrication Transport	310	0.50	155.00	0	0	0.00
Subtotal	*625*		*312.50*	*315*		*157.50*
3.0 Subcontracts						
Fabrication			2000			0
Subtotal			*2000.00*			*0.00*
4.0 Materials						
Classification			***Cost [$]***			***Cost [$]***
Compression/Tension Members			400.00			305.00
Steel plate for sign			50.00			50.00
Steel plates for connections			300.00			300.00
Cross-bracing			70.00			20.00
Drill Bits			20.00			20.00
Cleaning Supplies			15.00			15.00
Storage containers			40.00			40.00
Paint			100.00			15.00
Strapping/Pulley System			75.00			75.00
Box wrenches			140.00			140.00
Welding Materials			500.00			500.00
Nuts and Bolts			100.00			100.00
Display Poster			80.00			80.00
Miscellaneous			50.00			50.00
Subtotal			*3,430.00*			*1,710.00*
5.0 Total			**$76,315.50**			**$89776.50**

7 Acknowledgments

In order to complete this project, many individuals and organizations assisted the team. The team would like to thank Agate Steel for the donation of the steel and the time to create all the gusset plates. Additionally, the team received a large donation of nuts and bolts from Copper State Nut & Bolt Company.

The team also received assistance from Professor John Tingerthal for design suggestions. Professor Mark Lamer and his brother, Andrew Lamer, also assisted by providing the team with experienced welders. The mentees on this project included Kaitlin Vandaveer, Ashlee Anderson, Matt Rodgers, Sabrina Ballard. They successfully completed the display board for the steel bridge team.

8 References

[1] "STUDENT STEEL BRIDGE COMPETITION, 2015 Rules." 2015 National Student Steel Bridge Competition. ASCE, AISC, 1 Jan. 2014. Web. 30 Aug. 2014.

[2] American Institute of Steel Construction. (2010, June 22). Specification for Structural Steel Buildings. [Online]

9 Appendix A

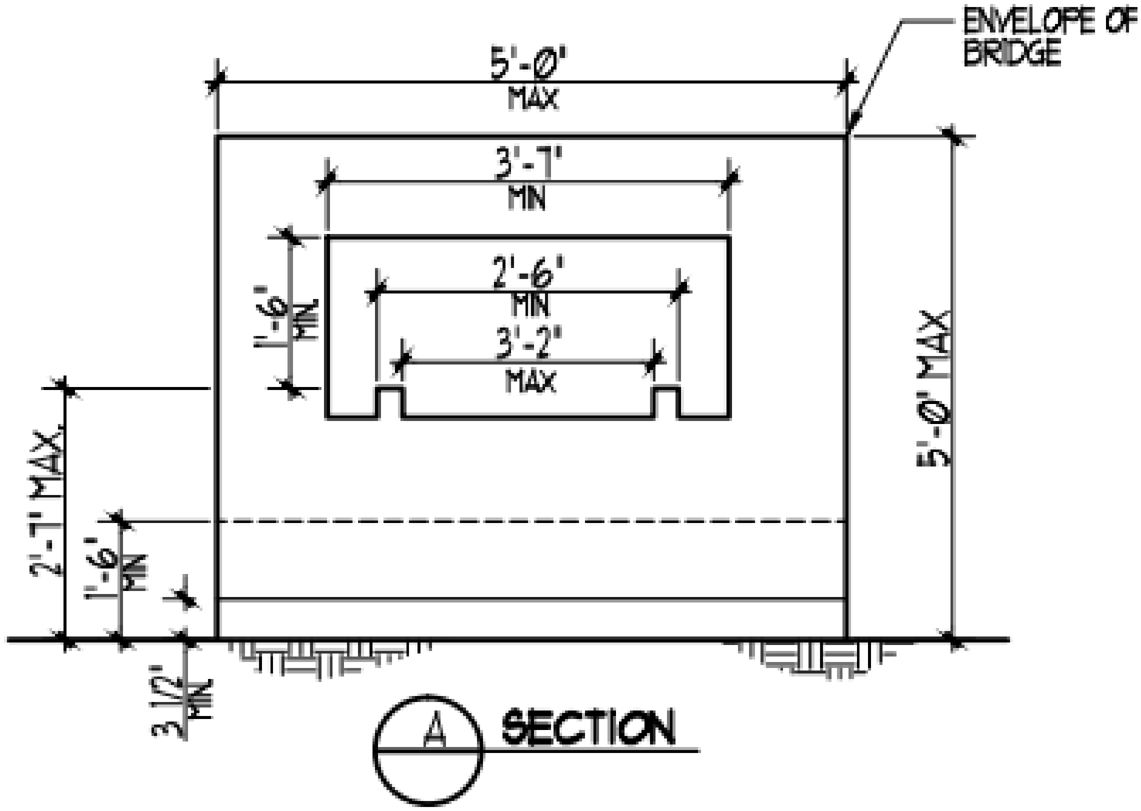

Figure A1: Bridge Envelope [1]

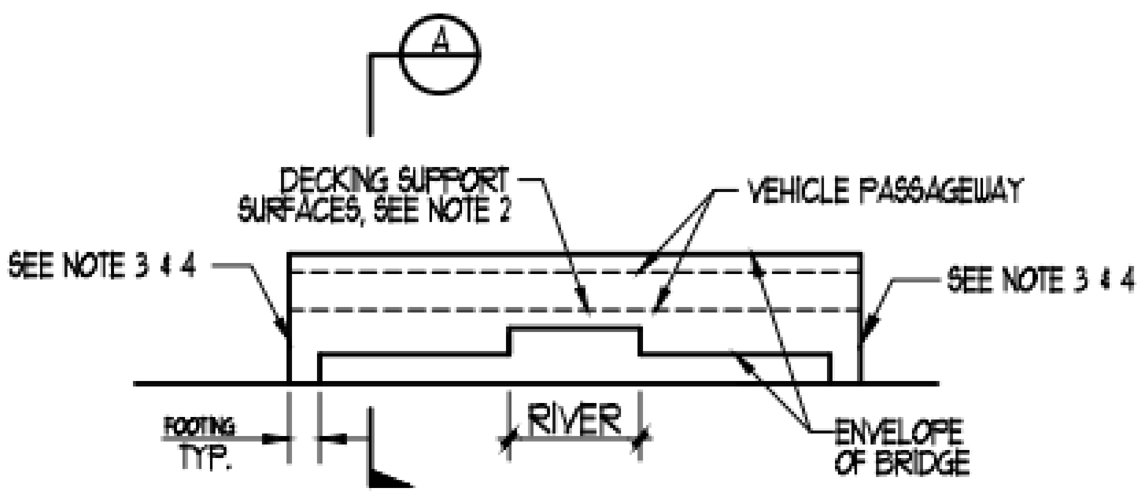

Figure A2: Profile of Bridge [1]

10 Appendix B

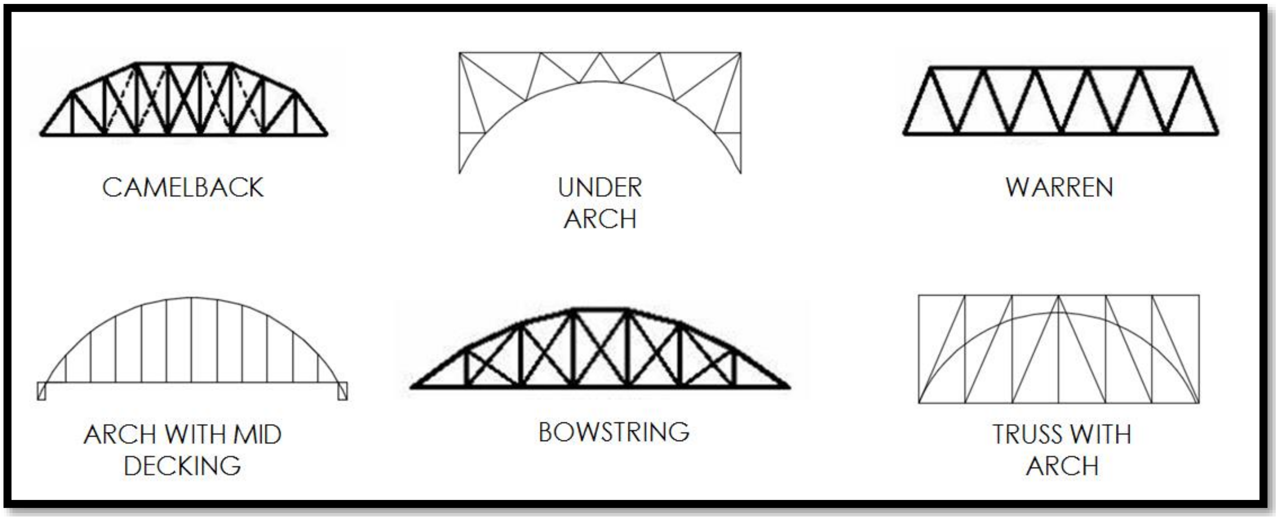

Figure B1: Design Alternatives

Table B1: Decision Matrix

Criteria	Arch with Mid Decking	Camelback	Truss with Arch	Warren	Bowstring with Crosses	Under Arch
Strength (25%)	5	5	5	5	5	5
Lightness (30%)	3	4	1	5	1	2
Aesthetics (10%)	5	3	2	1	3	4
Constructability (20%)	2	4	1	5	3	2
Fabrication (15%)	4	5	2	5	1	3
Final Score	3.65	4.3	2.25	4.6	2.6	3.1

11 Appendix C

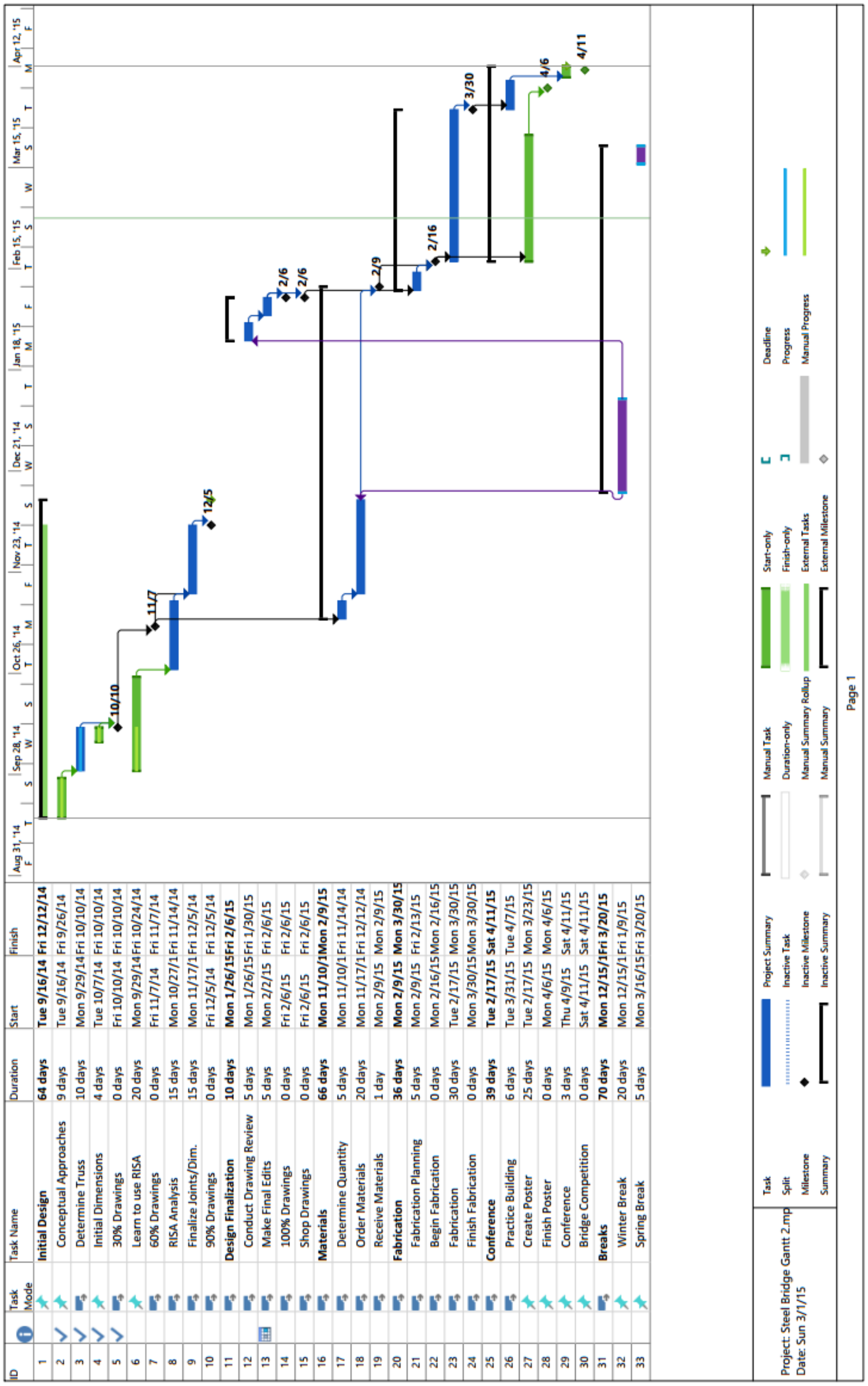

Figure C1: Initial Steel Bridge Schedule

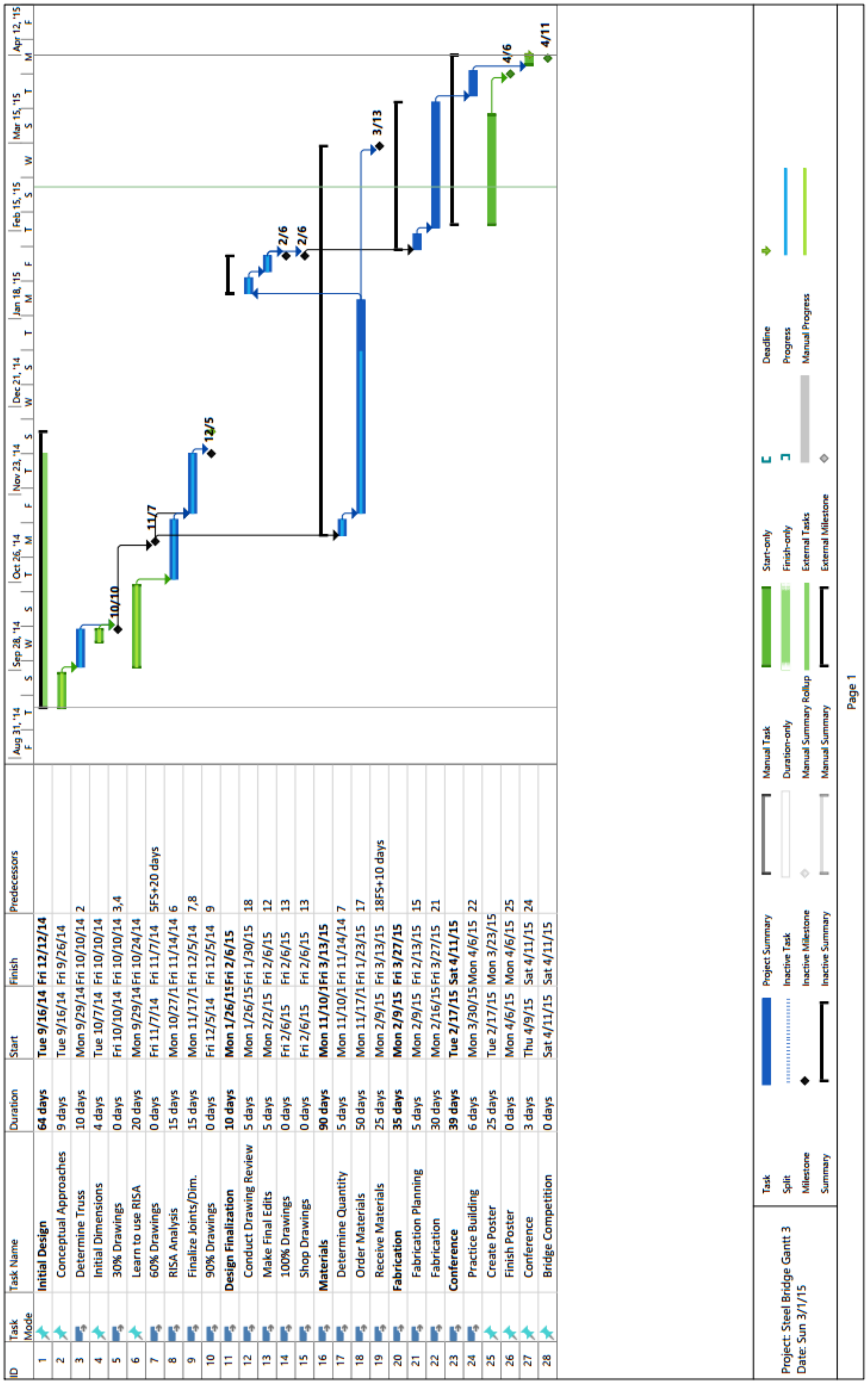

Figure C2: Updated Steel Bridge Schedule

12 Appendix D

Table D1: Billing Rate Calculations

Personnel Classification	Base Pay [$/hr]	Benefits [%]	Actual Pay [$/hr]	Overhead [%]	Actual Pay + Overhead [$/hr]	Profit [%]	Billing Rate [$/hr]
Project Manager	48.00	20	57.60	30	72.00	10	78.00
Conference Captain/Safety Engineer	45.00	20	54.00	30	67.50	10	73.00
Scheduling Engineer	40.00	20	48.00	30	60.00	10	65.00
Design Engineer	43.00	20	51.60	30	64.50	10	70.00
Intern	10.00	0	10.00	30	13.00	10	14.00

13 100% Steel Bridge Design Report

**Note all scales within design report are 1/2