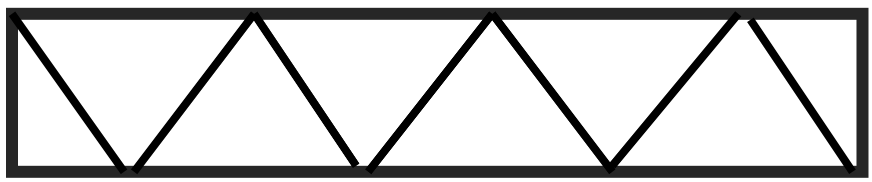
Northern Arizona University
American Society of Civil Engineers
Steel Bridge Competition 2016-2017



Final Design Report
May 9, 2017

<u>2016-2017 Steel Bridge Team</u>
Sabrina Ballard
Sean Hopper
Ryan Morofsky
Meg Stevens

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Acknowledgements

The 2016-2017 Northern Arizona University steel bridge team would like to acknowledge Page Steel, Agate, Copper State Nut and Bolt Company, and K-zell Metals for their generous donations for the bridge. The team would also like to thank our technical advisor Thomas Nelson and client Mark Lamer for assistance on this project.

1.0Project Understanding

1.1 Project Purpose

Annually, the American Institute for Steel Construction (AISC) holds a design competition for engineering students. In this competition, students are asked to design and build a 1:10 scale bridge made completely from steel. The bridges are constructed, loaded, and judged at the American Society of Civil Engineers (ASCE) student chapter conferences. The team has been selected to represent Northern Arizona University (NAU) and design, fabricate, and construct a steel bridge in compliance with the current year's rules. The goal is to design a bridge with the highest overall performance in the judging categories of display, construction speed, lightness, stiffness, construction economy, and structural efficiency. By winning the Pacific Southwest Conference (PSWC), the design will be granted a contract for the Luckiamute subdivision bridge.

1.2 Project Background

A new subdivision is being planned for construction along the banks of the Luckiamute River and the bridge will need to be finished before the subdivision can be built. There are water and sewer lines running parallel along the river bank that could possibly interfere with the bridge construction depending on which footings and span are chosen. The bridge will be built in an environmentally sensitive area where no damage to the banks is permitted. If the end of the bridge is a cantilever, it will not interfere with the water and sewer lines or damage the banks. The bridge must meet the minimum bridge clearance height of 15' due to rising water levels in the spring. If the job is finished before water levels rise, construction costs will be minimized. Deck, foundations, and approaches are not included in the bridge contract and will not be included in the design. The proposed bridge span is 200 ft. Serviceability, construction cost and duration, material cost, and esthetics are critical considerations when designing the bridge.

Figure 1.1 shows the proposed building envelope of the bride over the Luckiamute River. The materials will be moved from the staging yard, through the transportation zone and into the construction zone where the bridge will be constructed.

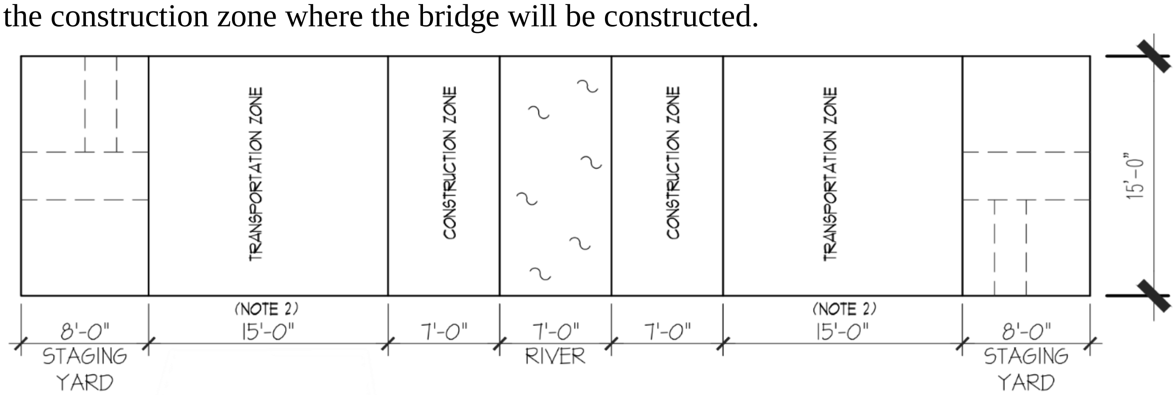


Figure 1.01 Proposed Building Envelope [1]

1.3 Technical Considerations

The bridge will be designed so the members are strong enough to withstand positive and negative moment, and vertical and lateral forces based on different loading combinations. The member's connections will be designed so they have sufficient bending moment and bearing capacity and can easily connect during timed construction. The legs will be designed to support the load placed on the members on any load case. The bridge will be braced laterally to prevent side sway when loading the bridge laterally and vertically. After the bridge has been analyzed and designed, technical consideration will focus on constructability and speed of construction. The design portion will involve designing a bridge that presents a high aesthetic value and being engineered to meet the standards described in the ASCE/AISC steel bridge 2017 rules. A total of 2500 pounds will be applied to the bridge for the vertical load test, and a 50-pound lateral load will be applied at two different locations on the bridge for the lateral load test. Structural analysis software will be used to determine the projected bridge deflection and to ensure the design will pass the load testing.

After the design is complete, fabrication methods and constructability will be coordinated to ensure that the materials used are feasible and construction methods are reasonable. Jigs will need to be constructed to ensure that all of the members are welded identically so no extra moments are developed in fabrication. The connections need to be precision cut so they are more easily connected to each other reducing deflection in the joints. Members will need to be cut to the appropriate design size and holes will be drilled in appropriate locations on the members to properly follow the design ensuring the design plans and rules are followed. Fabrication methods will maximize strength while minimizing the amount of material needed to satisfy the requirements of this technical challenge.

1.4 Potential Challenges

One potential challenge will be obtaining the steel members in the sizes and grade of steel that will be required. This will be overcome by asking various steel shops for donations or fundraising to purchase the steel that is necessary.

Once challenge will be meeting the constraints of this project including but not limited to the following:

- Bolt lengths less than 3”
- Member sizes under 36”x4”x6”
- Bridge model total weight under 303 pounds without penalty
- Threads on bolts shall be continuous
- Deck surface must safely support a 3’6” decking unit
- Cannot exceed vertical deflection of 2” in the vertical load test
- Cannot exceed ½” vertical sway in the lateral load test.
- Bridge deck cannot exceed 5’ in width
- Deck support surface cannot exceed 2’7”
- No bridge component can extend more than 5’ above the ground
- No bridge component or builder can touch the river
- No more than 6 builders
- No tools can weigh more than 15 pounds
- No more than two temporary construction piers
- Bridge construction time must be under 30 minutes without penalty but 45 minutes is allowed
- Bridge decking must be continuous along the span(s)

Another potential challenge will be minimizing the deflections of the bridge while also minimizing the weight of the bridge. This will be dealt with by constructing a decision matrix and optimizing the weight and deflection of the bridge in order to score the highest at the competition.

The timeline of this project is a potential challenge. The project must be fully completed before April 5th in order to compete in the Pacific Southwest Conference. In order to overcome this challenge, the team will aim to complete the 90% design by November 1, 2016. This will allow sufficient time to procure the materials, fabricate the members, and practice the timed construction.

1.5 Stakeholders

Some stakeholders of this project are the future owners of homes in Beaver Lodge Estates. This housing development is located adjacent to the Luckiamute River, thus a bridge would provide access to these new homes from across the river. They are stakeholders due to their need to travel across the river.

The NAU Civil Engineering Department and the NAU ASCE student chapter have a stake in the outcome of this project, as well. If this project ranks high at the competition, NAU ASCE and the Civil Engineering Department will receive recognition and will have an increased reputation.

2.0 Scope of Work

2.1 Task 1.0 Research

1.1 Competition Rules

The competition rules were read in order to determine the potential loads combinations that could be applied to the bridge, and to ensure the bridge meets all requirements.

1.2 Analysis Methods

Various structural analysis and design software was researched including RISA 2D, RISA 3D, Solidworks, and Bentley STAAD.pro.

1.3 Materials Research

Research was performed on grades of steel and the shapes of members to use.

2.2 Task 2.0 Fundraising

2.1 Bank Account

It was attempted to create a bank account, but required a unique tax identification number. Obtaining a tax identification for this capstone is beyond the scope.

2.2 Sponsorships

The team called and emailed local businesses to ask for donations and sponsorships.

2.3 Go Fund Me

A Go Fund Me page will be created and shared on social media in order to target donations from friends and family.

2.3 Task 3.0 Structural Analysis and Design

3.1 RISA Model

A RISA model of the bridge was developed. The load combinations for the loading at the conference were applied, and the deflections and member stresses were determined. All of the loads were multiplied by a factor of 1.2. This gives the bridge a 20% factor of safety, which can help account for any minor errors during the fabrication process. The base RISA model was refined in order to best meet the judging criteria. A final RISA model was generated including member lengths, steel types, and all potential load combinations, as shown in Appendix A.

1x1x1/16, 0.5x0.5x1/16, 0.75x0.75x1/16, and 0.5x1x1/16 HSS tubing along with ¼" rod was used for this design. All of the HSS tubing was designed to be A513 steel, which has a yield strength of 72 kips per square inch (ksi). The ¼" rod was designed to be A36 steel, which has a yield strength of 36 ksi. The members in RISA were "moment released" at the ends. This tells the software that the members will be bolted at this location instead of being fixed or welded together. The bridge was analyzed as having a "pin-pin" connection and also as having a "pin-roller" connection. This was done because the way the bridge will behave at the competition will be somewhere in between these idealized boundary conditions. Under the vertical load test, according to the RISA model, the worst case vertical deflection is 0.646 inches. The maximum lateral sway under vertical loading is 0.67 inches. Under the lateral load tests, the anticipated lateral deflection is 0.26 inches.

During the loading at the conference, the load will be applied first somewhere near mid-span, and the deflection will be measured. The second load will then be placed over the cantilever end and the deflection will be measured again. Because of this, the bridge design in RISA was analyzed under the application of just the load applied near min-span, and then was also analyzed when there was load near mid-span and over the cantilever.

3.2 Connection Design

The connections were designed to withstand the maximum moment as determined in RISA from the member forces by considering applicable moment capacity. A SolidWorks model was generated to determine locations of maximum stress, as shown in Appendix B.

3.3 Materials Analysis

After the steel was received, samples of the materials underwent tensile testing. The team recorded the force and displacement from each of these tests. The yield force was determined from using the 2% offset rule, and the yield stress was then calculated by dividing the yield force by the cross sectional area. The measured yield stress was then compared to the anticipated yield stress for that material. It was found that all of the tested yield strengths were higher than specified, which verified that the team received the correct grade of steel.

3.4 Fabrication Drawings

Shop drawings were created in AutoCAD with a plan view, profile view, details, and section cuts for plate members, as shown in Appendix C. These plans were given to KZell Metals so plates could be precision cut with a laser cutter to specified dimensions.

2.4 Task 4.0 Fabrication

4.1 Construction Drawings

Construction drawings were created in AutoCAD and show an overall side view, front view and side view of the bridge, and details of members and connections, as shown in Appendix C. This was done for the team to use during fabrication and construction.

4.2 Jig Creation

Jigs for the span members, cantilever members, lateral bracing members, center span members, and leg members were designed and constructed to minimize fabrication variations in dimensions and to help create parts that are constructed to specified dimensions. This ensured that the capacity of the bridge is in accordance to the design.

4.3 Fabricate Components

Components will be fabricated using prescribed techniques to minimize distortions and maximize components strength. Members will be cut to specification and any needed holes will be drilled using guides to ensure accuracy and correct member placement when being constructed.

4.4 Finalize Welding and Fabrication

Welds will be made approximately every six inches in order to minimize distorting and weakening of the metal. If material with a yield strength equal to or greater than 50 ksi, the steel will need be preheated to 50-125 degrees Fahrenheit before it is welded to ensure a full weld.

4.4.1 Material surfaces will be prepared by sanding and grinding the surface layer. All members will be inspected for quality and uniformity.

4.5 Inventory of Bridge Components and Final Layout

A final inventory of parts and members will be performed before construction practice begins.

2.5 Task 5.0 Construction

5.1 Construction Methods

Construction methods will be developed and tested. Construction methods that meet the conference criteria will be brainstormed.

5.2 Method Selection

After all construction methods have been tested and timed, a final construction method will be chosen. This will include assigning who will be constructing at conference, which side of the river they will be on, and what their role will be.

5.3 Construction Practice

The chosen method will be practiced under a similar setting to what is expected at conference. The building envelope including the footings, river, construction zone, and transportation zone will be taped out, and each time the bridge construction is being practiced, a mentee will keep track of the time and violations during building. After each practice, the pros and cons will be discussed and improved upon for the next construction practice.

2.6 Task 6.0 PSWC

The display board provided by the mentees will be printed. It will be printed in order for the display board to be set up next to the bridge on display day and be judged on aesthetics. The team will construct the bridge and display the poster provided by mentees for the display day at the PSWC for judging. The team will also construct the bridge at the conference during timed construction. If the bridge is constructed in the allowable time and has not been disqualified, the bridge will undergo the vertical and lateral load tests.

2.7 Task 7.0 Project Management

7.1 Project Schedule

A project schedule and Gantt chart was developed to ensure on time completion of the project, as shown in Appendix D.

7.2 50% Design Report/ Plans

A 50% design report and plan set will be submitted to the client and technical advisor for redlines and comments.

7.3 Final Design Report

A final design report will be written after the PSWC Steel Bridge Competition. The report will include the 100% design, results from the PSWC, and discussion on the performance of the bridge.

7.4 Final Presentation

A presentation will be given at the Undergraduate Research and Design Symposium (UGRADS) which will convey the objective and scope of the project, the design and analysis of the bridge, and results of the bridge at the PSWC Steel Bridge Competition.

7.5 Website

A website will be generated including team information, the final project proposal, final design report, AutoCAD drawings of the bridge, and results of the PSWC conference.

7.6 Team Meetings

The team is holding weekly meetings in order to ensure progress on the project.

7.7 Client communications

Meetings were held with the client, grader, and technical advisor in order to receive feedback on the design and project deliverables. The technical advisor meetings provided feedback about the design and technical aspects of the bridge, meetings with the client will helped guide the constraints of the bridge design, and meetings with the grader provided clarity on course deliverables and feedback from redlines.

2.8 Exclusions

Exclusions of this project include arranging transportation and lodging for PSWC. Additionally, the design team is not liable for injury that occurs if the scaled steel bridge is used for anything other than its intended use. If the design team's steel bridge is selected to be designed as a full scaled bridge, the materials and construction labor shall be provided by other subcontractors.

2.9 Broader Impacts

Through completing this project, skills other than those directly relating to this project will be learned. Teamwork skills will be improved through working with the team for every aspect of the project. Through corresponding with sponsors, clients, and technical advisors, communication skills will improve. These skills will aid in a future career in civil engineering, since most projects will involve communication with subcontractors and clients and teamwork between coworkers in other departments.

3.0 Identification of Alternatives

3.1 Footings

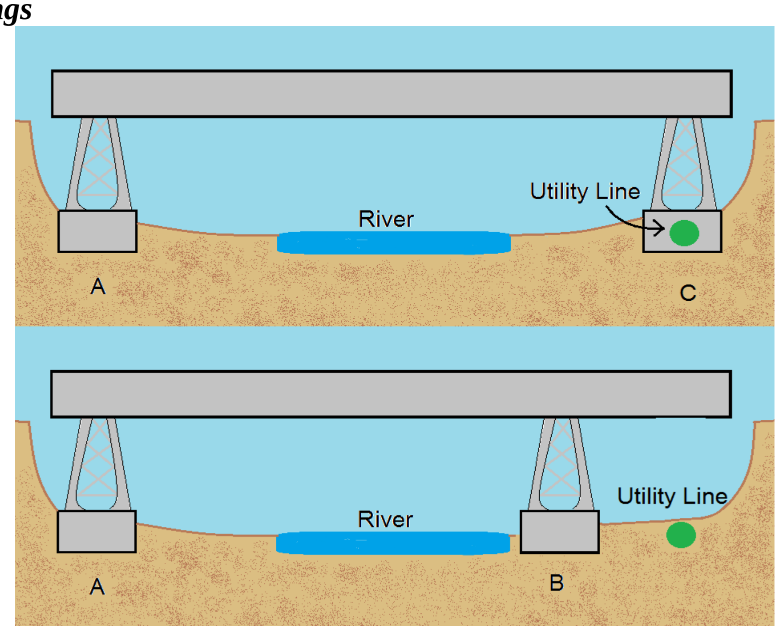


Figure 3.1 Footing Options

The team had an option to choose footing AB or footing AC, as shown in Figure 3.1.

3.2 Bridge Types

The team decided if the bridge was going to have a top chord or not have a top chord.

3.3 Bridge Members

The team decided on the basic geometry of the main bridge members. Bridge members explored were 4x6" HSS tube, triangular mini-trusses, square mini-trusses, and rectangular mini-trusses.

3.4 Lateral Bracing

Six different types of lateral bracing were explored that had identical member sizes, but varying geometry.

3.5 Deflection Reduction

The team explored increasing member sizes, member weights, and the overall moment of inertia of the bridge in order to reduce the vertical deflection of the bridge.

3.6 Substructure

The configuration and location of the substructure along the span of the bridge was determined.

3.7 Connections

The team decided between gusset plate connections and slip connections for the primary bridge members.

3.8 Member sizes, thicknesses, and grade

Various member types were explored such as round tubing, square tubing, rectangular tubing, and solid rod. The thicknesses of the tubing explored were 1/16", ⅛", 3/16", and solid tubing. The size of the rod explored was ⅛", ¼", 3/16", and ½" diameter. 1/16", ⅛", 3/16", and ¼" plate was explored for the plate connections. The grade of steel explored for all materials was A513, A36, and A992 steel.

4.0 Identification of Selected Designs

4.1 Footings

The team created a decision matrix to first decide which foundation was going to be chosen, as shown in Appendix E. The footing options were scored based on the cost, vertical deflection, and lateral deflection. They were scored 1,3, or 9 where 9 is the highest score, and 1 is the lowest score. The cost was weighted the highest, 60%, because the "cost" of the bridge is how the bridge is ranked at the competition. The vertical deflection was ranked as 30% because the deflection has an impact on the cost of the bridge. The lateral deflection was weighted the lowest, 10%, because it is a pass or fail test and does not impact the cost of the bridge as long as the bridge passes the lateral load test. Footing AB has a cantilever end, and footing AC is a simple span bridge. The option with the cantilever resulted would not result in a cost penalty and footing AC would result in a cost penalty, which is why the team ranked footing AB 9 and footing AC 1. For footing AB, the mid span deflection would be lower compared to the simple span bridge, which would have a larger span and thus a larger deflection, thus for vertical deflection, AB was ranked 9 and AC was ranked 3. The option with the cantilever would deflect more when pulled on the end than the simple span bridge compared to the simple span bridge, thus AB was ranked 3 and AC was ranked 9. The weighted score was determined by multiplying the raw score by the weighted percent. The weighted scores for each option were added up and the option with the highest weighted score was chosen. Footing AB was chosen because it had a weighted score of 8.4 while footing AC had a weighted score of 2.4.

4.2 Upper Chord

A decision matrix was created in order to determine if the bridge was going to have an upper chord or not, as shown in Appendix F. The potential options were given weights 1, 3, 9 for aesthetics, construction time, weight, and strength, where 9 is the highest and 3 is the lowest. The team prioritized weight and construction time, thus those were given the highest weights. The strength was given a weight of 20% because it was believed that either option could be made stronger with additional design and increased member size, and aesthetics was given the lowest weight because the aesthetics of the bridge did not have as big of an impact of the bridge score as the weight and the deflection. The raw scores for each option was multiplied by the weighted percentage. Not having an upper chord resulted in the highest weighted score, thus was selected for the bridge design.

4.3 Bridge Members

A basic RISA model was created for the members being 4x6" HSS tube, two-dimensional mini trusses, triangular mini-trusses, square mini-trusses, and rectangular mini-trusses. All options had identical loading and lateral bracing. A bridge with 4x6 HSS tubing as the main members deflected 6 inches. Comparing the mini-trusses, the option with the two dimensional mini-trusses deflected the most (5 inches), and the rectangular mini-trusses deflected the least (2.5 inches). The weight of each option was also compared; the rectangular mini-truss option weighed the most, and the HSS tubing weighed the least. The team created a decision matrix and weighted deflection as 75% because the team wanted to create a bridge that would not get disqualified due to excessive deflection. Weight was weighted as 25% because the bridge would not get disqualified for weighing too much. Based on the RISA model results, each option was scored in the decision matrix, as shown in Appendix G. Rectangular mini-trusses had the highest score, thus the team selected to use rectangular mini-trusses for the main span members.

4.4 Lateral Bracing

The lateral bracing options were analyzed in RISA. The lateral bracing that resulted in the lowest lateral and vertical deflection was selected for use on the bridge. In determining the amount of lateral bracing required for the bridge, the team first applied lateral bracing every three feet along the bridge. The team then deleted the lateral braces that would be in the center of the river because they would be difficult to construct at the competition. The location and number of lateral braces were adjusted until the lateral sway was under 0.75 inches and the deflection under the later load was under 0.375 inches, and the weight was the smallest. The team selected these values to be the limiting deflections because the team wanted the bridge to deflect no more than 75% of the maximum allowed at the competition (1 inch maximum lateral sway and 0.5 inch maximum lateral deflection).

4.5 Deflection Reduction

The bridge was deflecting over 2 inches, thus the team came up with potential alterations to the design that would decrease the deflection. A decision matrix was created and the options were compared, as shown in Appendix H. Deflection and weight were both weighted as 50% because the purpose of the alternative was to decrease the deflection, but the team also did not want to add a substantial amount of weight doing so, which would ultimately decrease the conference score. Each alternative was analyzed in RISA. According to RISA, the substructure located at approximately mid-span would result in the lowest deflection and lowest weight of 300 pounds, thus it was scored the highest. Increasing the member sizes increased the bridge weight to be over 350 pounds. Increasing the member thickness resulted in a significant decrease in deflection, however, the weight of the bridge increased dramatically (approximately 400 pounds). The substructure was selected as the design because it had the highest weighted score.

4.6 Substructure

The substructure went through several iterations. Each design was tested in RISA and checked to see if member sizes were commercially available. The substructure was first placed in approximately the middle of the span. The location and geometry of the substructure varied slightly from the initial idea. Iterative RISA models were created in RISA, and the location and geometry that resulted in the lowest deflection and connections that would be feasible to construct was selected.

4.7 Connections

The gusset plate design and slip connection design was scored in the categories of fabrication ease, construction time, and weight in a decision matrix, as shown in Appendix I. Construction time was weighted the highest as 65% because the team wanted a construction method that would result in a fast construction time at the competition. Weight was weighted the second highest because the team wanted to minimize weight. If the team was unable to construct the bridge under the 45 minute time limit, the team would be disqualified, however, if the bridge weighed more, the bridge would not be disqualified, which is why construction time was weighted as higher than weight. Fabrication ease was weighted the lowest because the team believed that as long as there was time in the schedule to feasibly design the connections, the difficulty of the connection should not play a major role in the selection of the connection. A score was assigned under each category for each connection design option. Although the gusset plate had a higher weighted score, the slip connection had a higher weighted score, thus was chosen for the design.

4.8 Member shape, thicknesses, and grade

The member shape, thickness, and grade was selected by optimizing the RISA model. The member shapes were selected based on their corresponding weight and deflection. Each member's initial thickness was 1/8" and then was either increased or decreased based on the weight and deflection from the resulting RISA model. Changes to the RISA model were made by either changing the member size or the thickness, but not both at the same time. The deflection and weight of the initial RISA model and the model with the changes was then input into the steel bridge competition scoring sheet [2]. The option which would result in the higher overall score was chosen. This process was repeated multiple times in order to optimize the shapes and member thicknesses.

The grade of the steel members was chosen to be what was readily available; A36 steel (36 ksi) was selected for the solid rod, and A513 steel (72 ksi) was selected for the HSS tubing. If A992 steel (50 ksi) was used for the connections, then the plates were only required to be 1/16" thick to withstand the induced bending forces. If A36 steel (36 ksi) was used, the plates would need to be 1/8". A plate with the same dimensions but a smaller thickness would weigh less than the option with the thicker plate, thus 50 ksi steel was selected for the plates.

5.0 Testing and Analysis

5.1 Testing

A mock-up of the connection design was created to determine the fabrication feasibility. After the mock up was created, the team brainstormed more ways to improve the design. Connection design improvements include the holes in the second plate to have space for the welds, and also a second bolt hole in all of the plates, which would decrease the overall weight.

Materials analysis was performed using the Tinius Olsen machine. A 24-inch section of each size and shape of material was cut. Any hollow sections had excess steel welded into the end so the machine grips would not crumple the ends. These were then tested in tension in the machine to determine the yield strength. These results were compared to the expected results based on cross-sectional area and grade.

6.0 Final Design

The final design of the steel bridge can be seen in the RISA model in Appendix A, as well as in the fabrication drawings in Appendix C. The beam bridge is a cantilever, utilizing the footings A and B (see Figure 3.1 for footings). The bridge span is comprised of 14 mini trusses. Each mini truss is comprised of ¼" rod, ¾"x3/4"x1/16" HSS, 1"x1"x1/16" HSS, and 1"x1/2"x1/16" HSS and measures 2'-11 ¼" x 4 ½" x 3 ½". Each mini truss will connect to the other via a male-female joint. These joints are comprised of 1/16” plate and hollow 1” tube. The lateral bracing is comprised of ½” x ½” x 1/16” HSS. The bridge is supported on four legs. Each leg consists of ¾” x ¾” by 1/16” HSS and are welded to 1/16” and ⅛” plate. The legs will be connected to the mini trusses with 1/16” plate. The substructure consists of 1” x 1” x 1/16” HSS, ¾” x ¾” x 1/16” HSS, and 1/16” plate. All bridge components will be held together using ⅜” Grade 8 bolts, varying from 1” to 3” in length.

7.0 Conference Results

There were 18 schools that attended the Pacific Southwest Conference. The bridge was constructed in 17 minutes and 14 seconds with four builders and zero temporary piers. During timed construction, the team dropped 6 items, which resulted in a penalty of 1 minute and 30 seconds. After penalties, the construction speed was 18.73 minutes which placed the team in 4th. The team placed 3rd in display. The bridge had a constructed weight of 243 pounds, which placed the team in 8th. The aggregate deflection is the deflection from the right side of the bridge plus the deflection of the left side of the bridge and the deflection of the cantilever end. The bridge's aggregate deflection was 4.41 inches which placed the team in 12th. The maximum deflection of the bridge was 2.3 inches which resulted in a $4,000,000 load test penalty added to the economy score and a $10,000,000 load test penalty added to the efficiency score. The bridge's economy score was $7,746,667 which was calculated based on the total time taken to construct the bridge, number of builders, number of temporary piers, and load test penalties. The bridge's efficiency score was $16,840,000 which was calculated based on the bridge weight, aggregate deflection, and load test penalties. determined using Equation 2. The team placed 6th in economy and 12th in efficiency. The overall score was determined by adding the economy score to the efficiency score. The team placed 9th overall with a score of $24,586,667.

8.0 Reflection

The primary cause of the bridge deflecting more than anticipated was due to fabrication difficulties. The team had the plate connections precision cut in order to ensure the bolt holes would align and the plates would be able to slip into each other. The first plates that were precision cut from Page Steel were not to a high enough precision, thus the team had to find another location who would be able to cut the plates to a higher precision. Each connection consisted of three plates welded together that were designed and modeled to act as one solid piece. To make the plates act together, the team initially planned on welding the perimeter of the plates together. However, after welding the first set of connections, the team soon discovered that the MIG welder the team had, was burning through the steel even on the lowest heat setting. After finding out that the MIG welder was too powerful, the team tried to purchase a TIG welder that would be able to weld the perimeter of the plates. Unfortunately, the team did not have enough time or money to order another set of plates with a greater thickness or was able to purchase a different welder. Instead, internal spot welds were used to fuse the plates together. It is now believed that this caused the plates to act as three separate plates rather than one plate. This issue could have been fixed by ordering another set of plates with a greater thickness that would be able to be fully welded with a MIG welder, buying a TIG welder, finding a TIG welder that the team would be able to borrow, or having the connections externally fabricated.

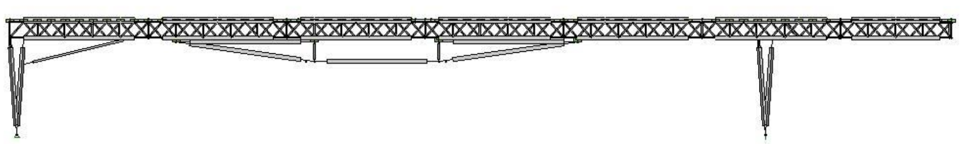
Another issue that could have led to additional deflection was that all of the members were not precision cut to the exact same length. This led to some of the mini-truss top or bottom chords being longer than others. When the bridge was constructed, not all of the top chord members were in contact with the other top chord members of its connecting mini truss. This caused the bridge to deflect significantly until the two top chord members were pressing against each other. The team tried to remedy this by shimming each chord behind the joint plates to align each member with the next truss. This improved the issue but did not completely fix the problem. This could be avoided in the future by having all bridge members professionally fabricated, or by continuing to cut and add material to the members until they were all perfectly aligned.

References

[1] "ASCE - AISC Student Steel Bridge Competitions", *Aisc.org*, 2016. [Online]. Available: http://www.aisc.org/content.aspx?id=780.

[2] "Scoring Spreadsheet". *Nssbc.info*. N.p., 2017. Web. 2 Mar. 2017.

Appendix A – RISA Model



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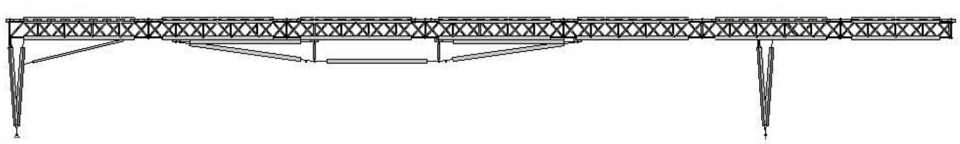
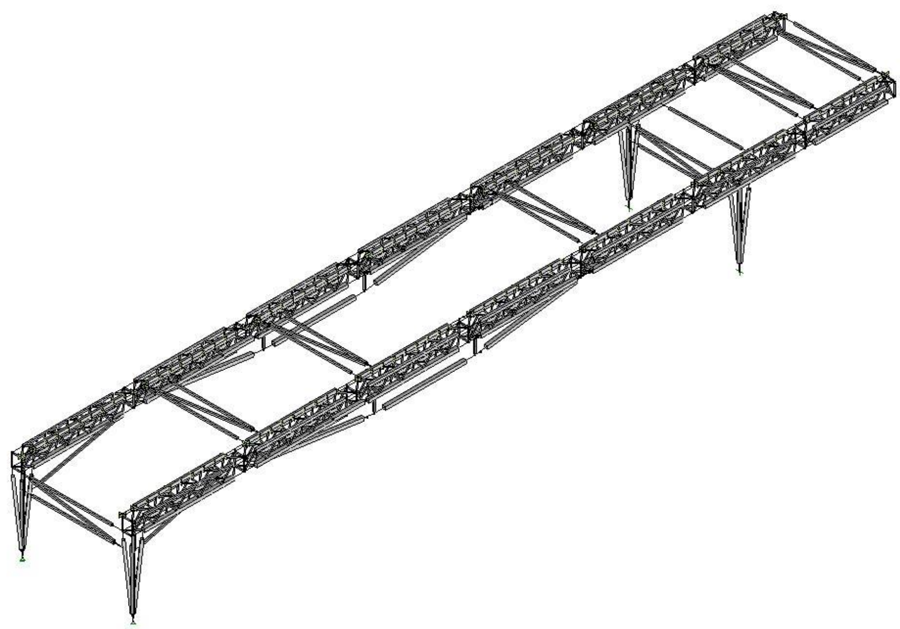
	Side View	Final Design.r3d



Northern Arizona University	2017 Steel Bridge	SK - 1
SMB, SJH, RNM, MS	Side View	Feb 28, 2017 at 4:14 PM
		Final Design.r3d



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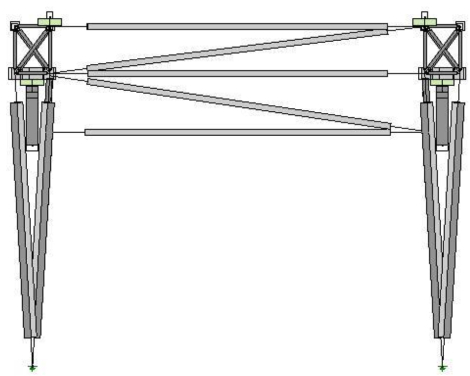
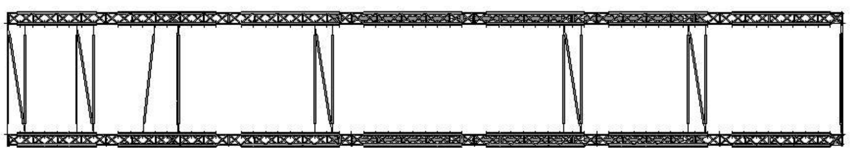
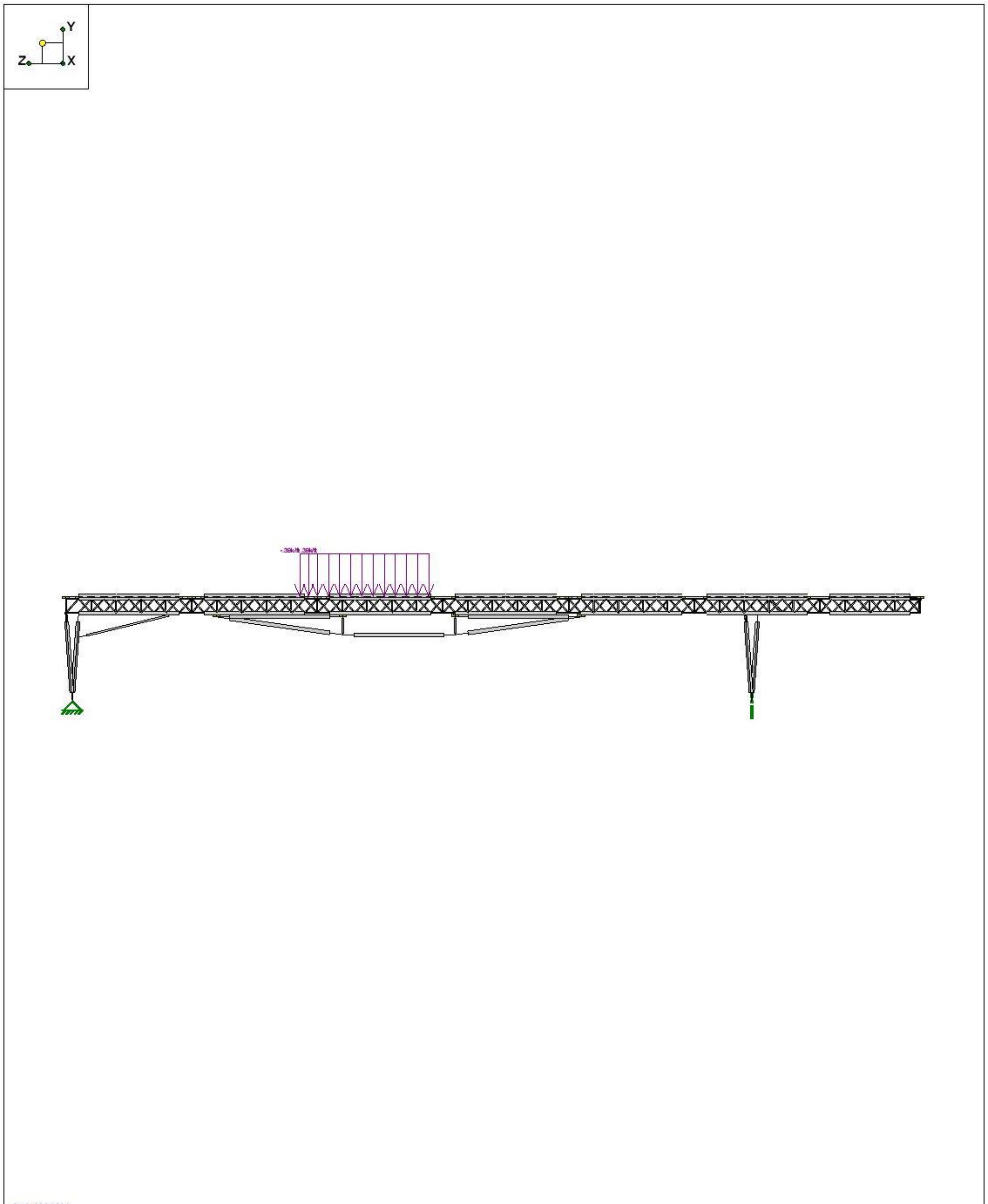
	Isometric View	Final Design.r3d



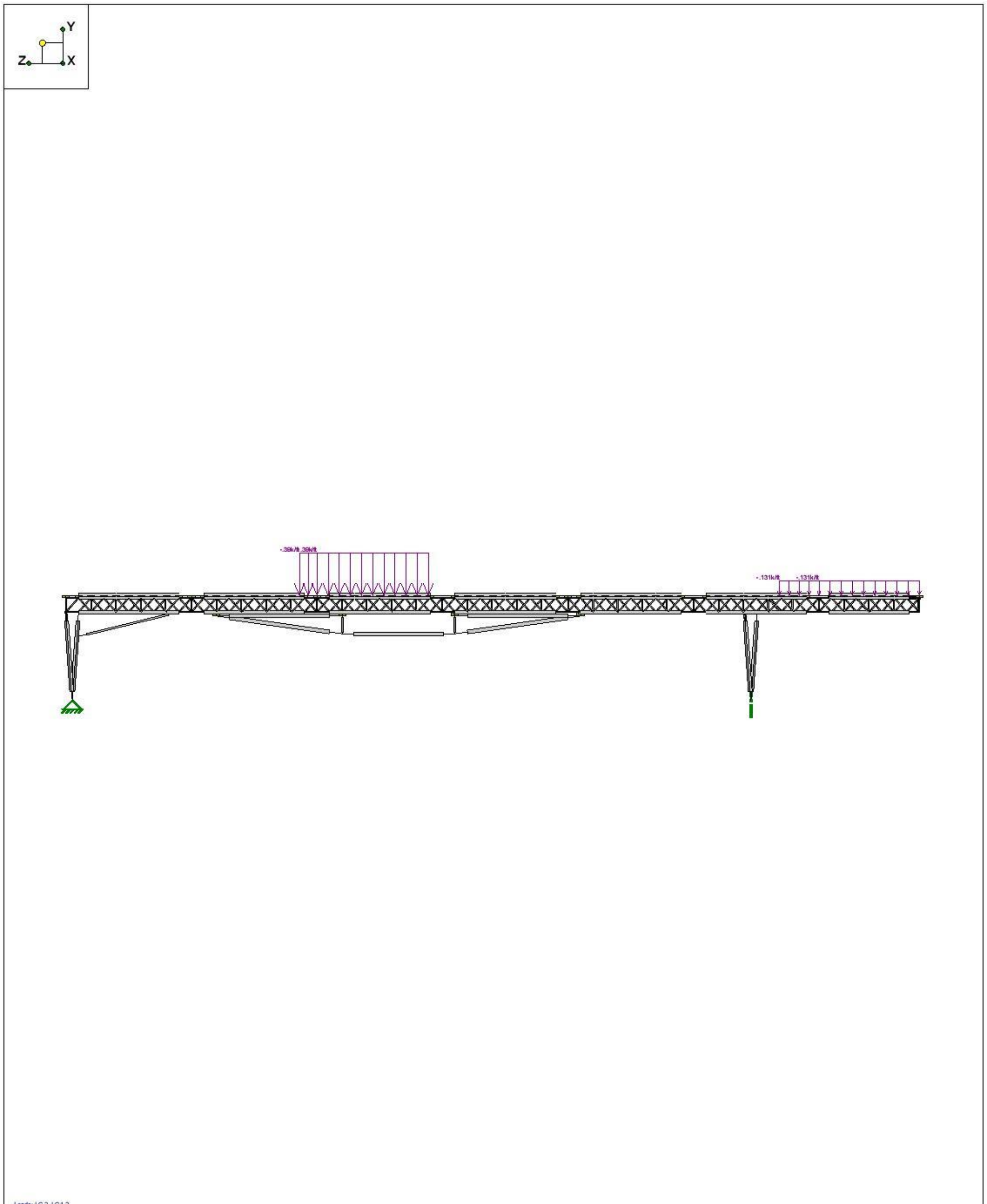
Northern Arizona University		SK - 3
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:18 PM
	Left View	Final Design.r3d



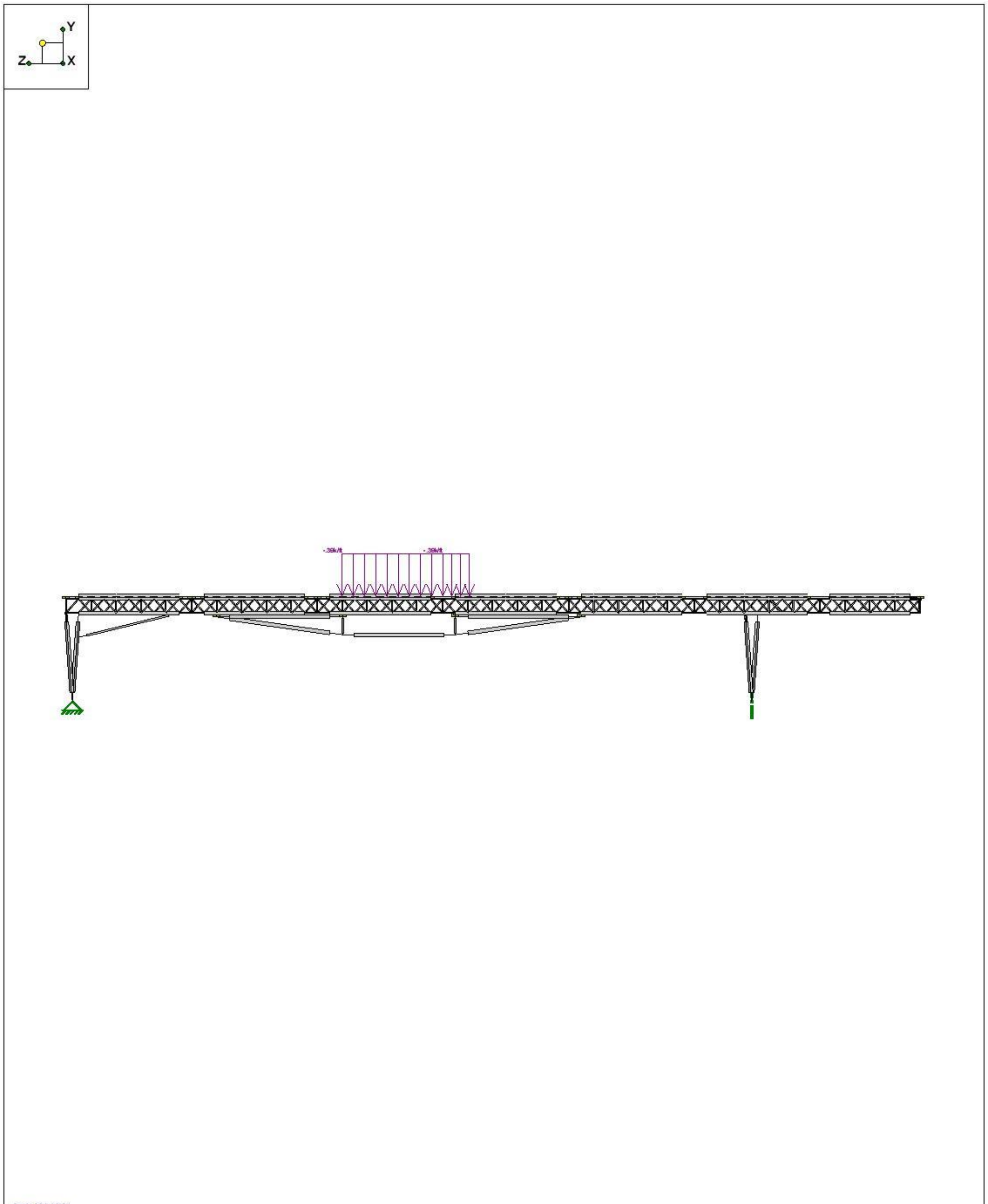
Northern Arizona University		SK - 4
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:19 PM
	Top View	Final Design.r3d



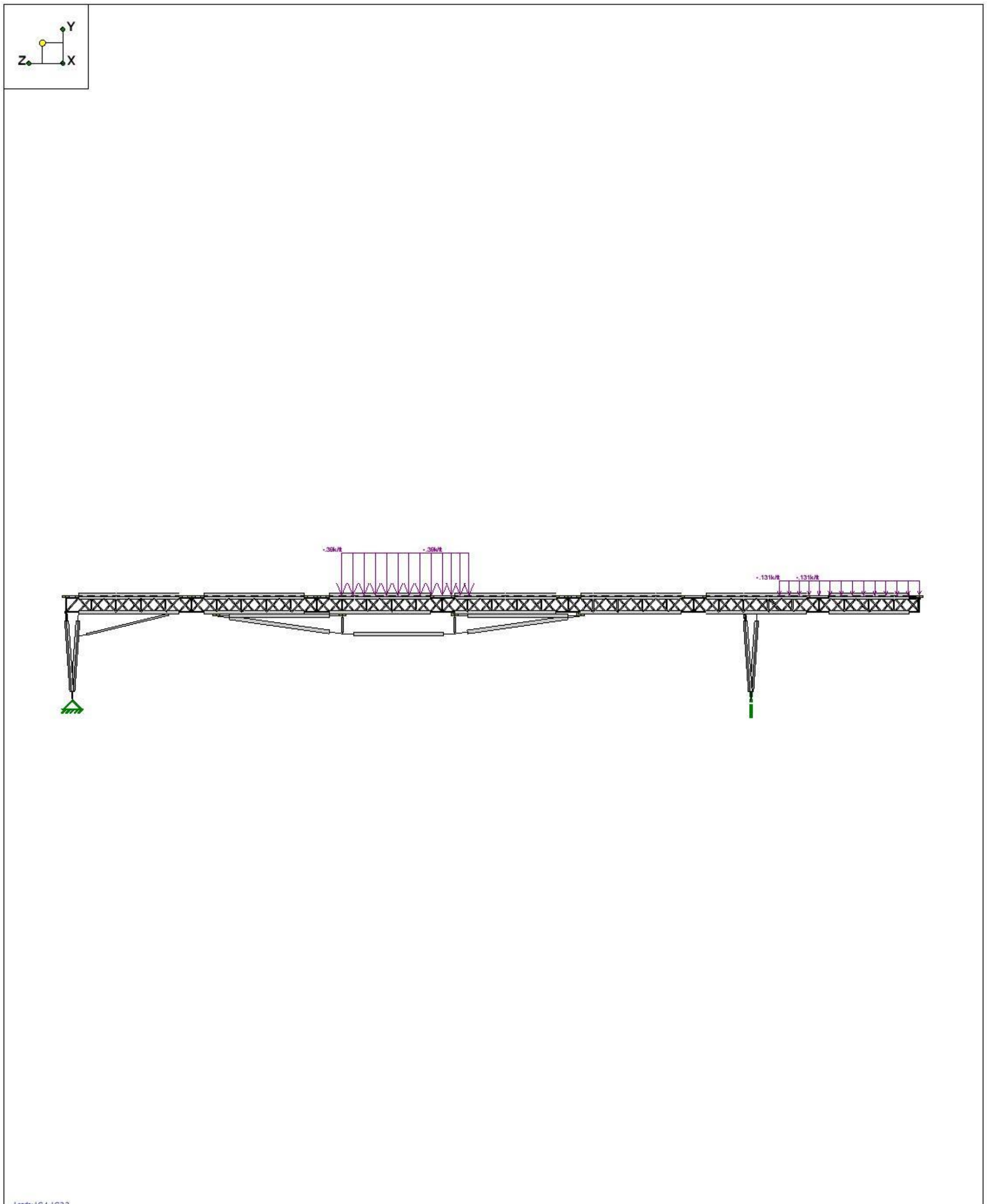
Northern Arizona University		SK - 5
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:29 PM
	Load Case 1-1	Final Design.r3d



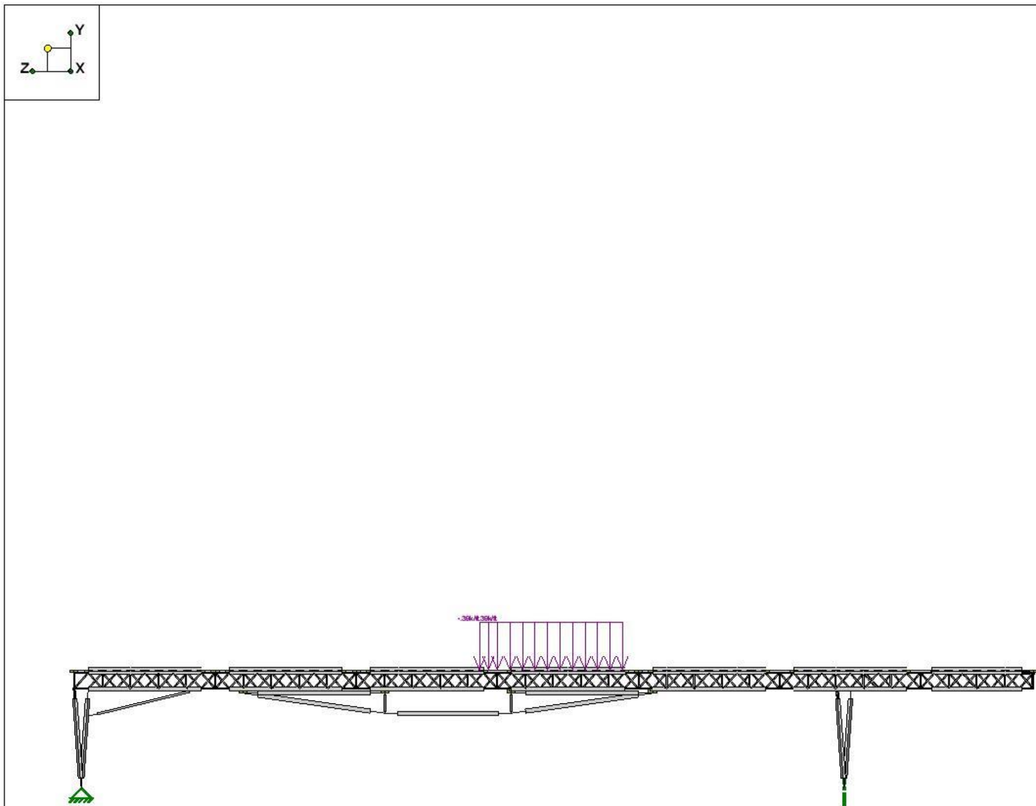
Northern Arizona University		SK - 6
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:30 PM
	Load Case 1-2	Final Design.r3d



Northern Arizona University		SK - 7
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:30 PM
	Load Case 2-1	Final Design.r3d

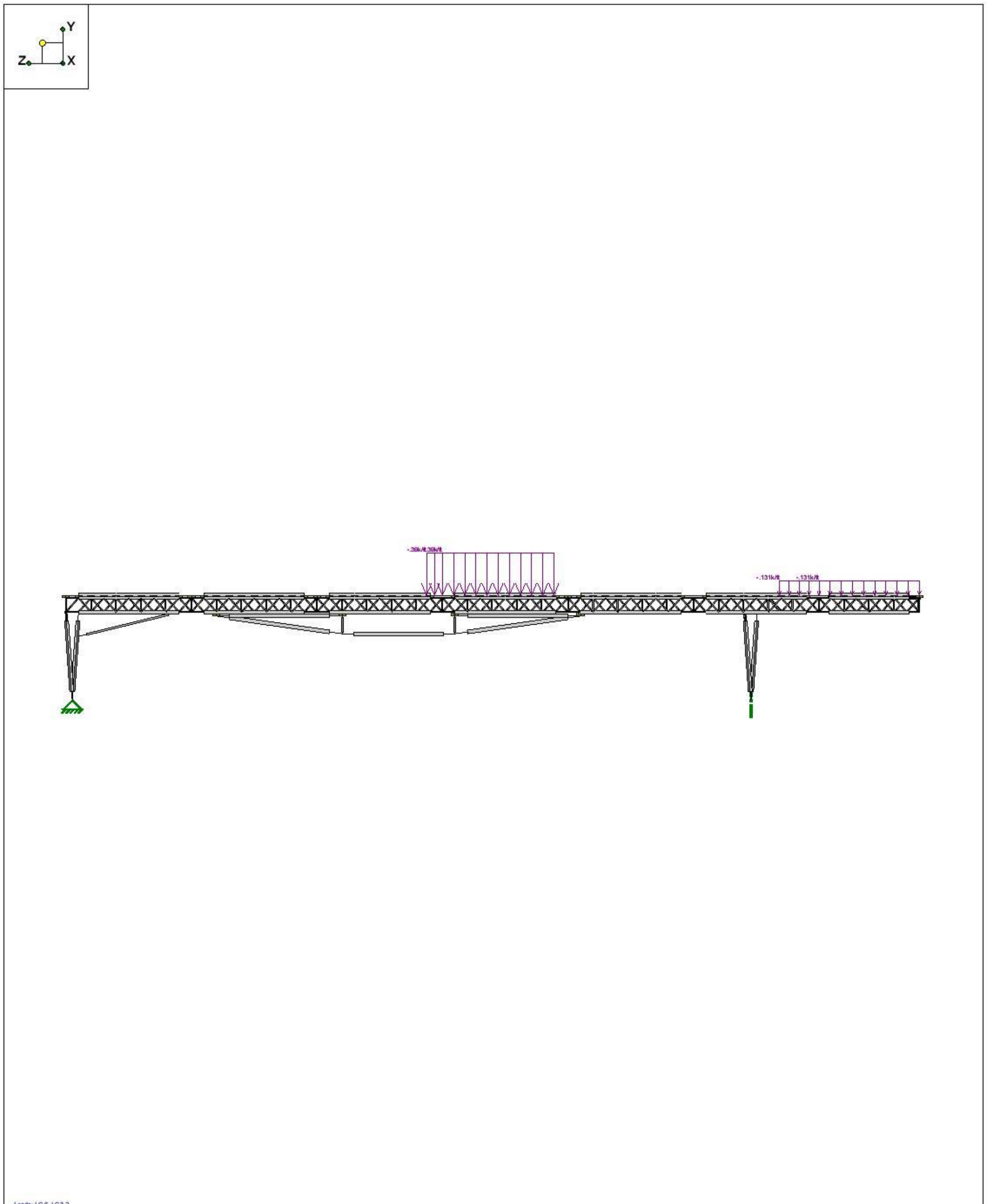


Northern Arizona University		SK - 8
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:31 PM
	Load Case 2-2	Final Design.r3d

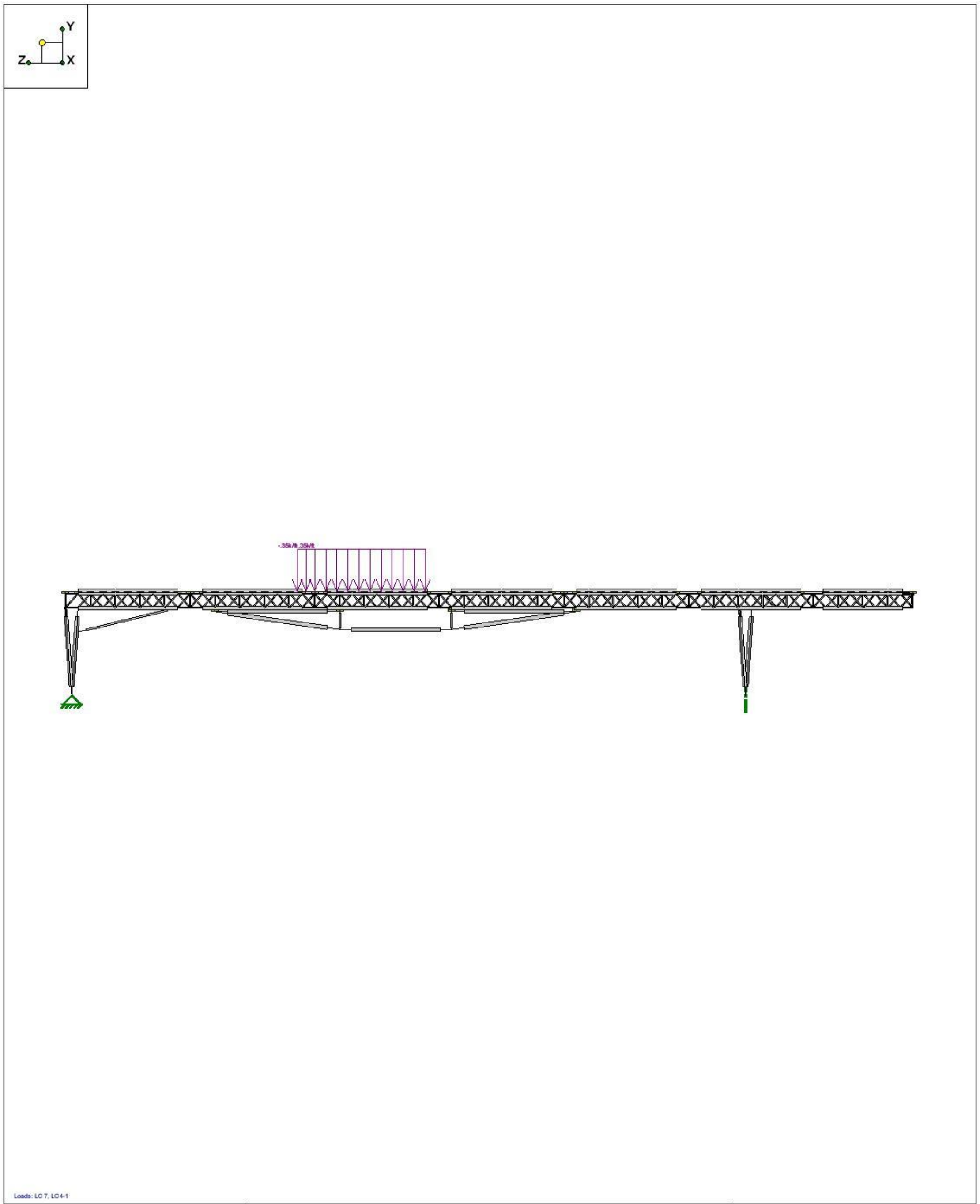


Loads: LC 5, LC3-1

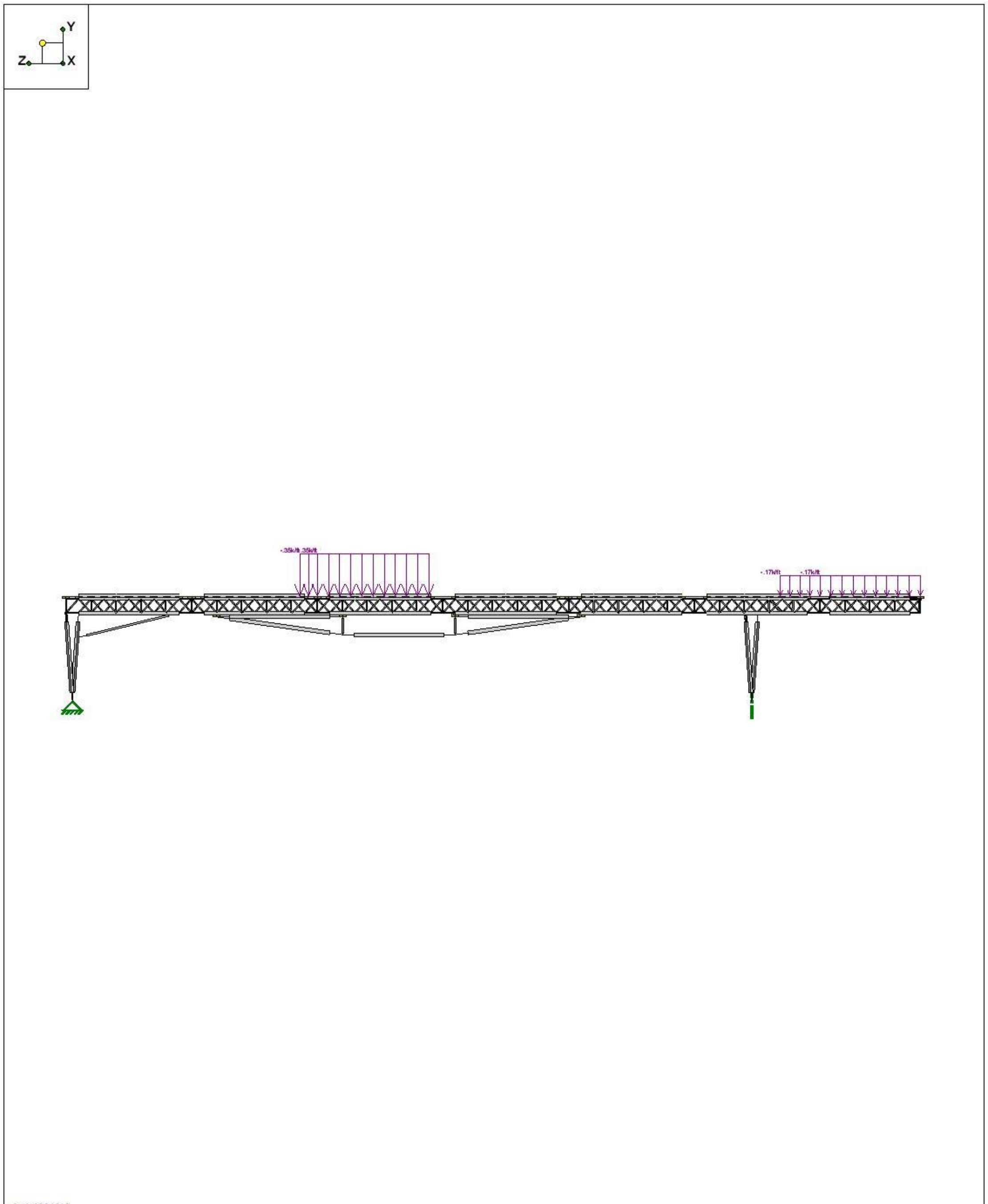
Northern Arizona University		SK - 9
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:32 PM
	Load Case 3-1	Final Design.r3d



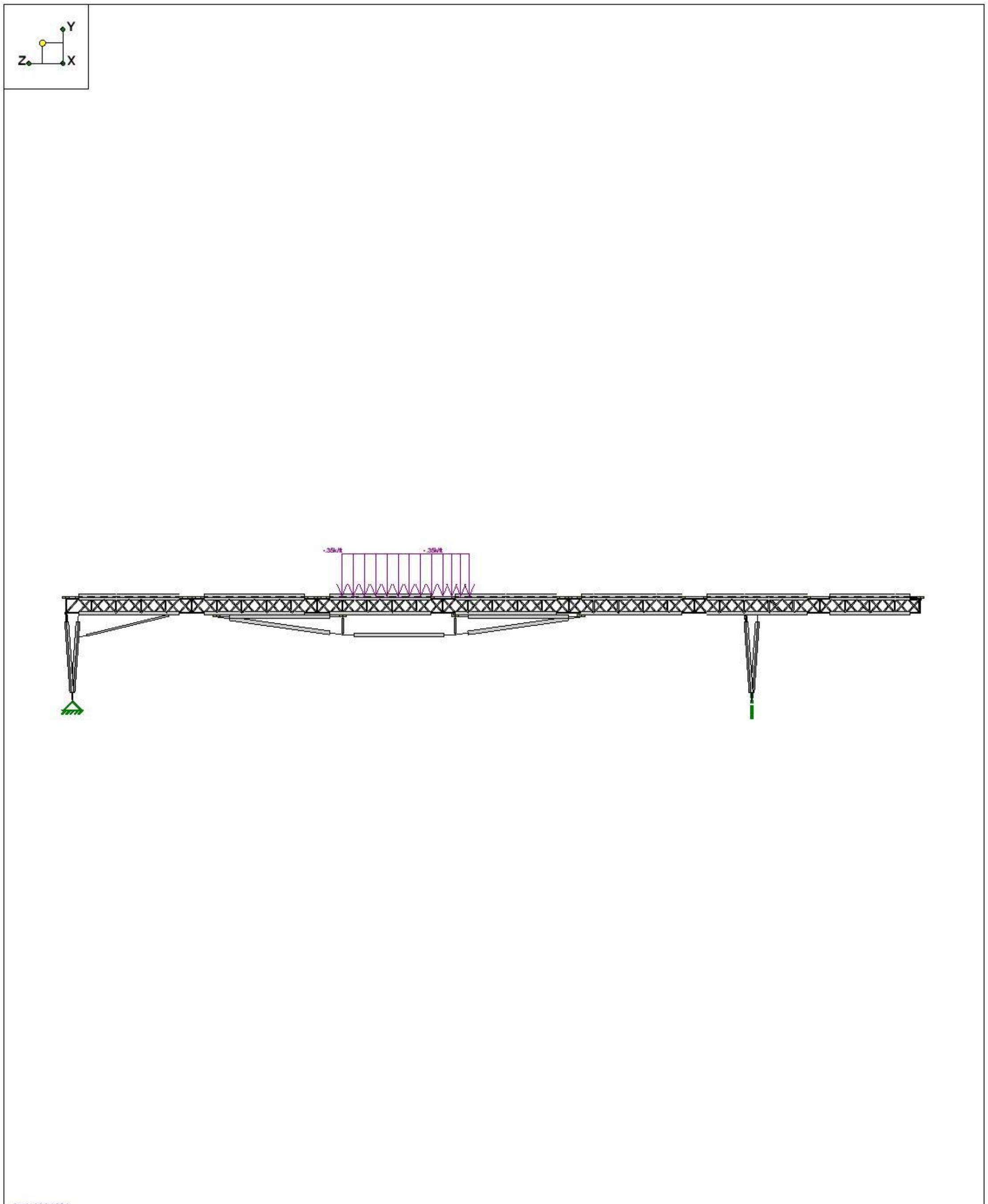
Northern Arizona University		SK - 10
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:33 PM
	Load Case 3-2	Final Design.r3d



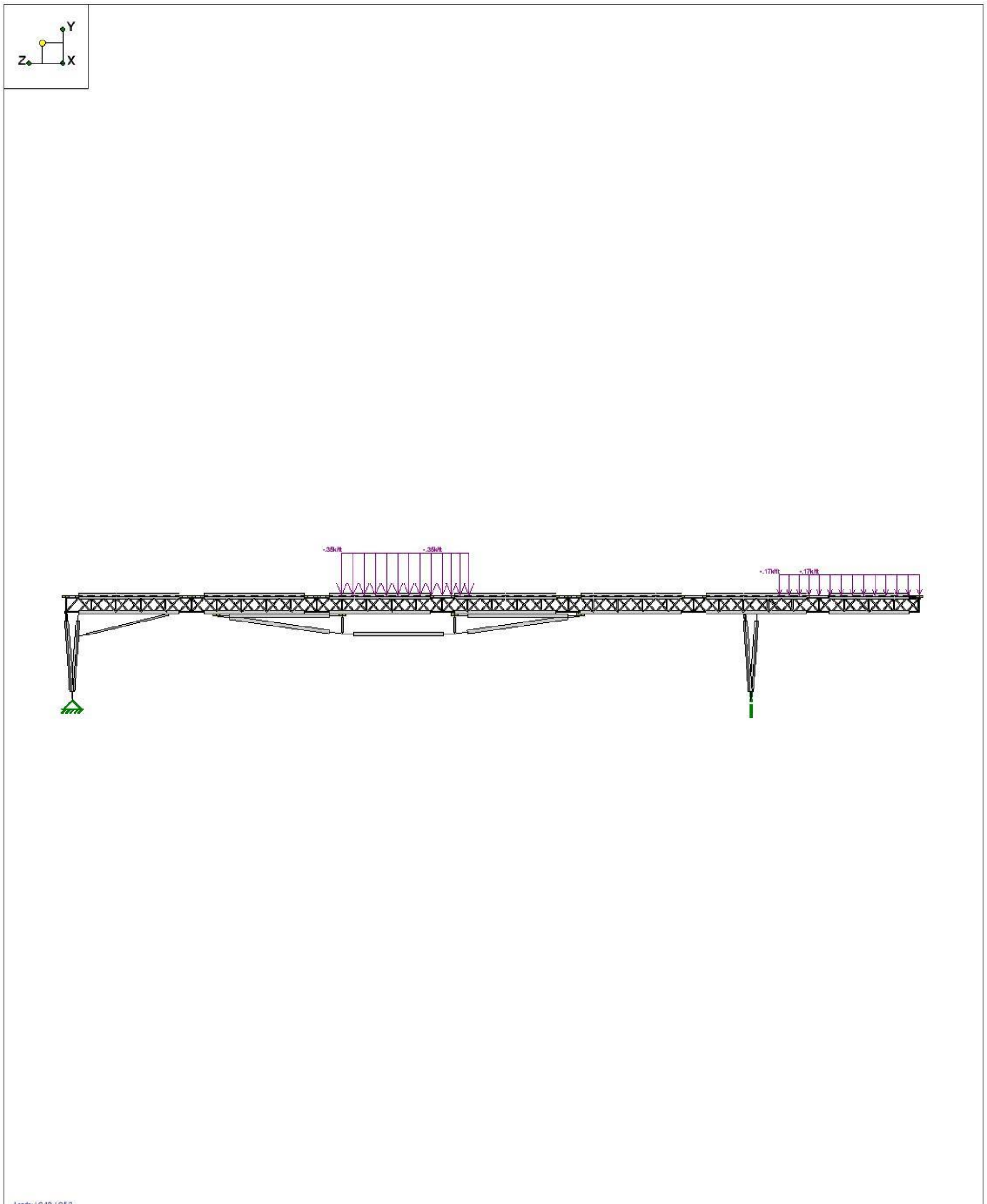
Northern Arizona University		SK - 11
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:34 PM
	Load Case 4-1	Final Design.r3d



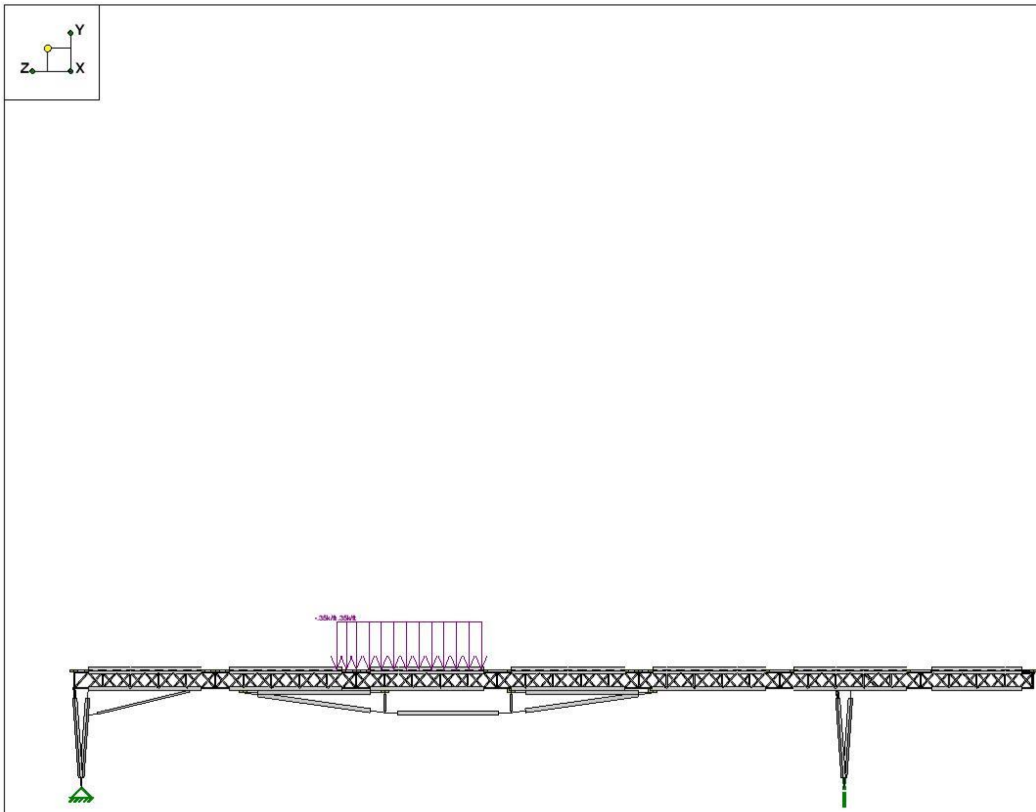
Northern Arizona University		SK - 12
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:35 PM
	Load Case 4-2	Final Design.r3d



Northern Arizona University		SK - 13
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:38 PM
	Load Case 5-1	Final Design.r3d

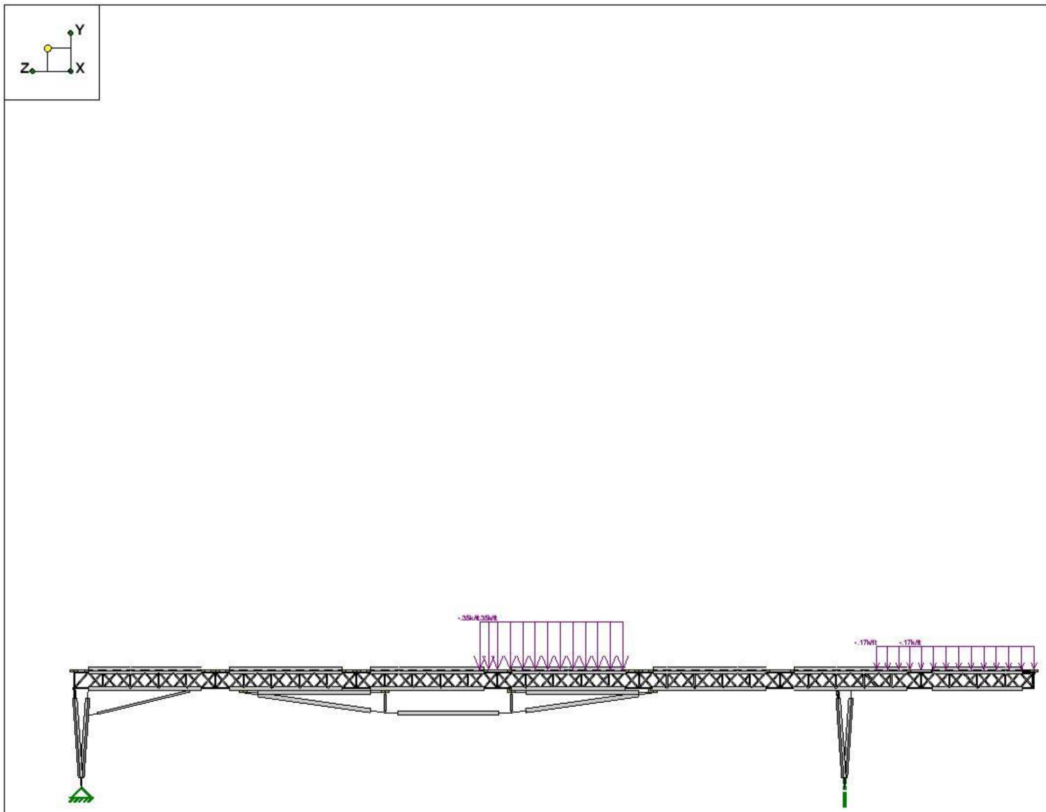


Northern Arizona University		SK - 14
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:38 PM
	Load Case 5-2	Final Design.r3d



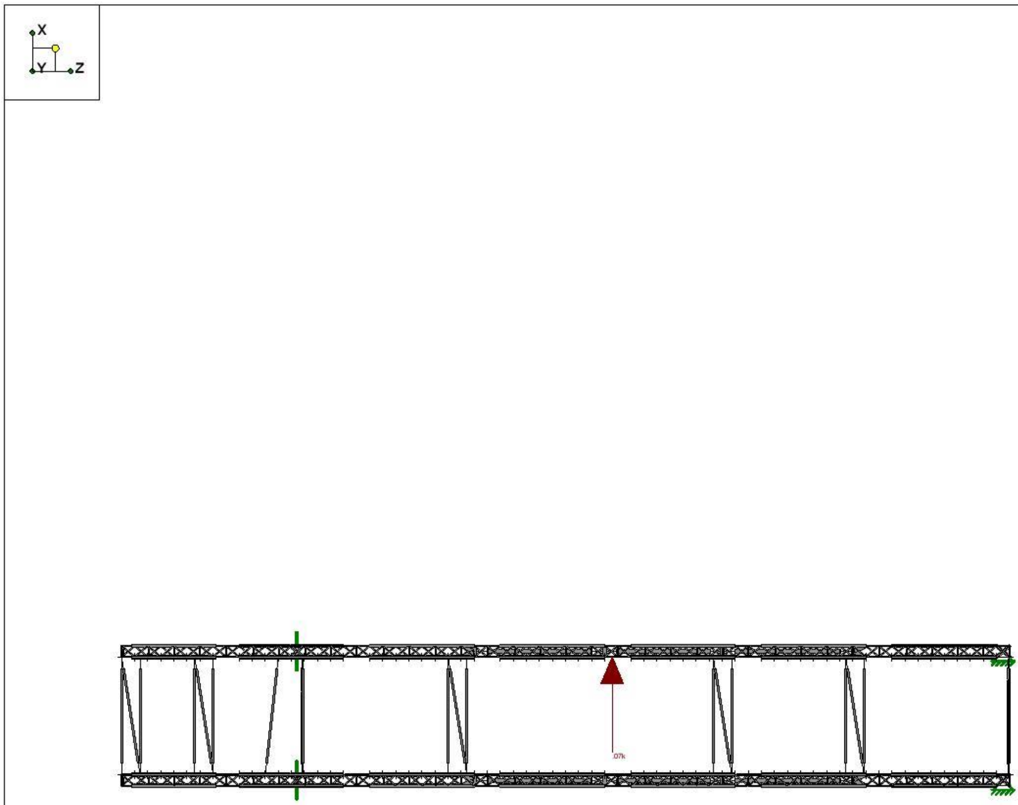
Loads: LC 11, LC6-1

Northern Arizona University		SK - 15
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:39 PM
	Load Case 6-1	Final Design.r3d



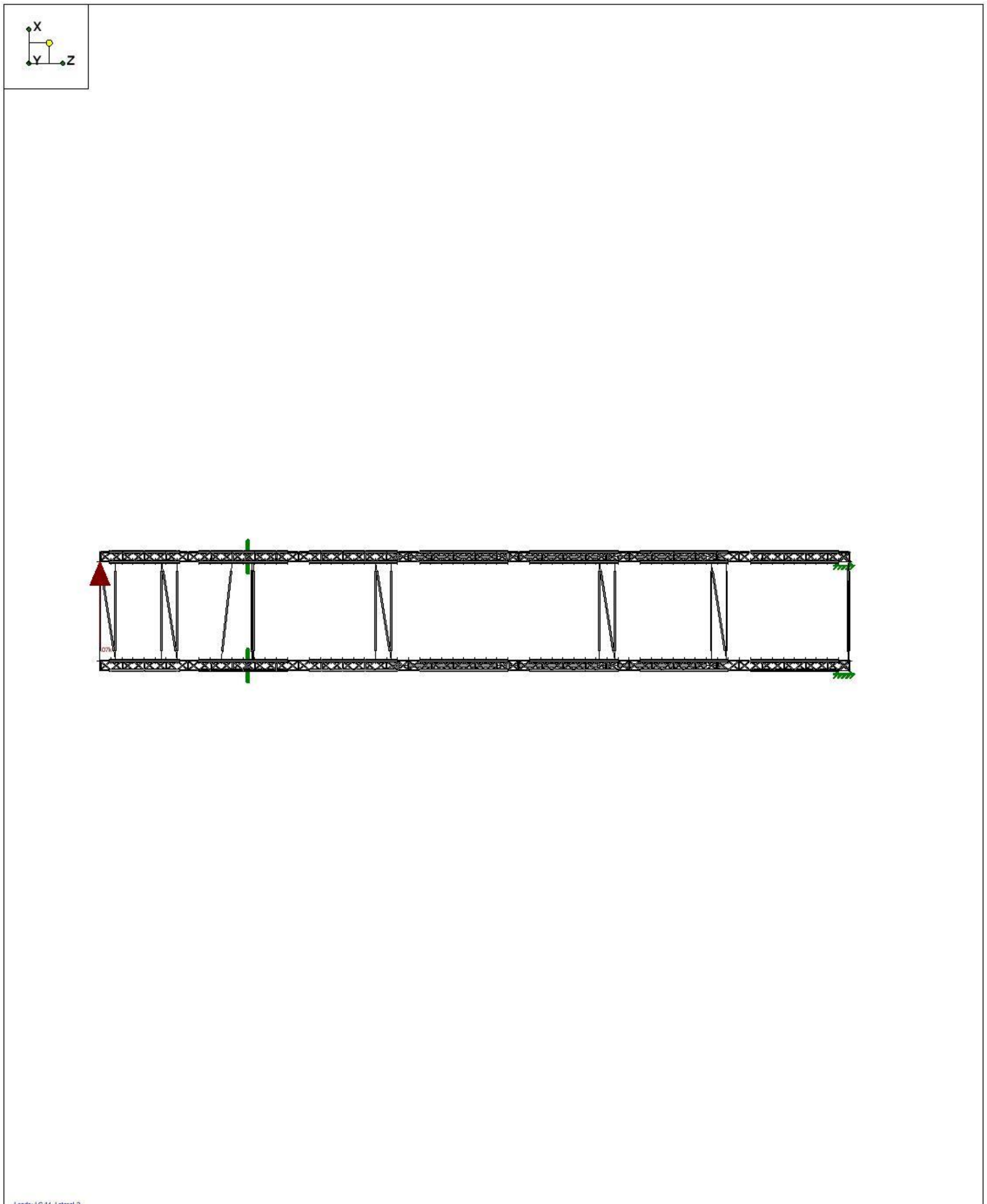
Loads: LC 12, LC6-2

Northern Arizona University		SK - 16
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:40 PM
	Load Case 6-2	Final Design.r3d

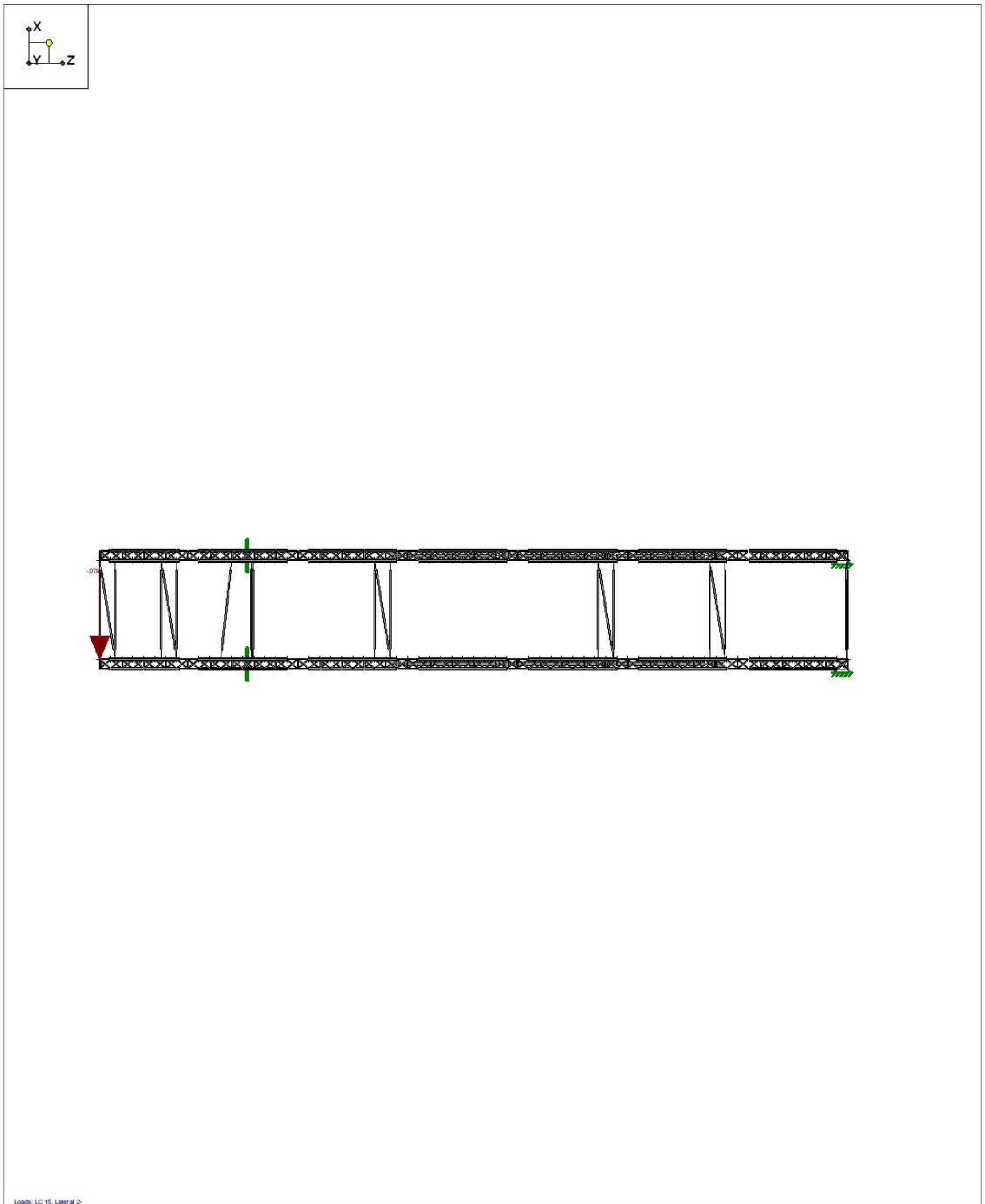


Loads: LC 13, Lateral 1

Northern Arizona University		SK - 17
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:41 PM
	Lateral Load Case 1	Final Design.r3d

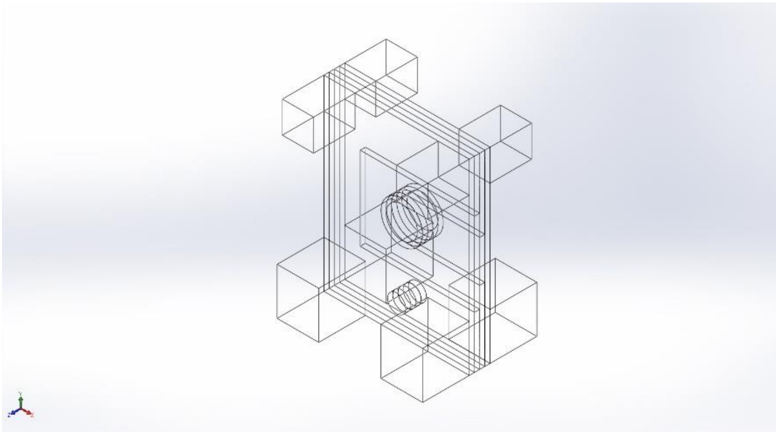


Northern Arizona University		SK - 18
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:43 PM
	Lateral Load Case 2	Final Design.r3d



Northern Arizona University		SK - 19
SMB, SJH, RNM, MS	2017 Steel Bridge	Feb 28, 2017 at 4:43 PM
	Lateral Load Case 3	Final Design.r3d

Appendix B – Solid Works Connection Model



Simulation of modified complete joint

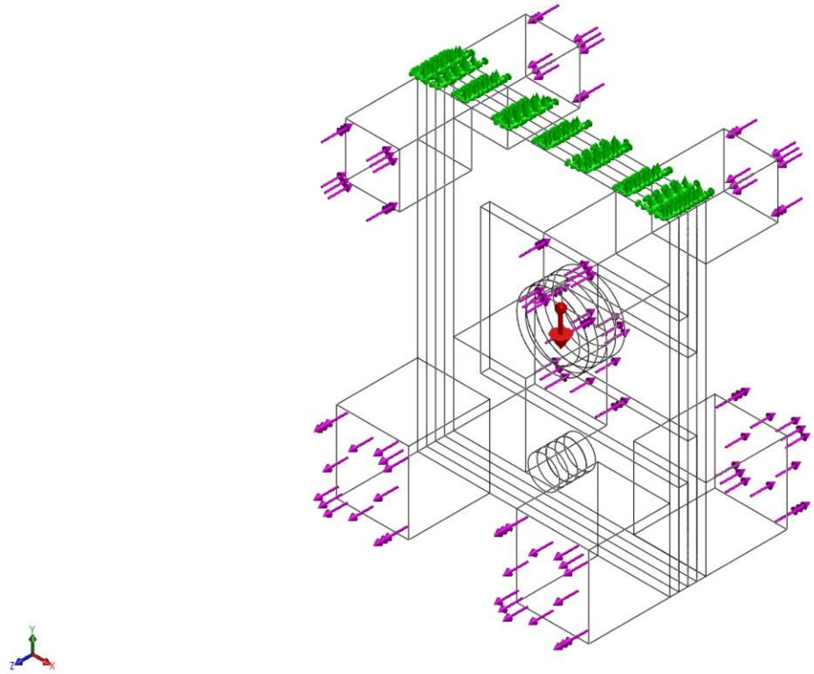
Date: Tuesday, January 24, 2017
Designer: Solidworks
Study name: Static 4
Analysis type: Static

Table of Contents

Description

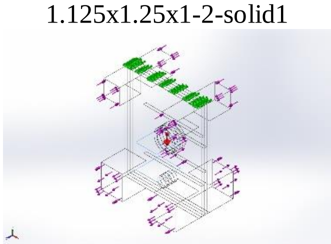
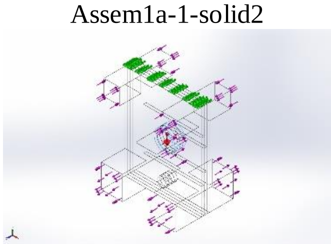
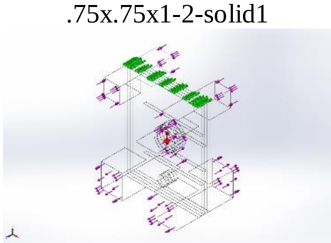
No Data

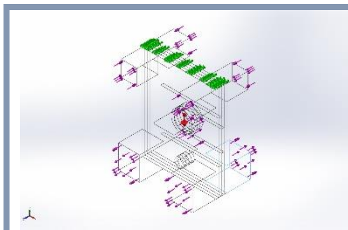
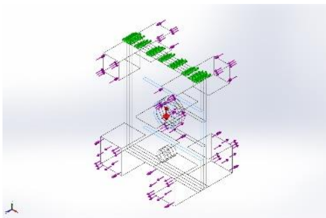
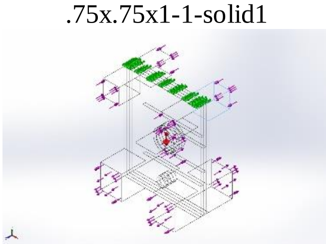
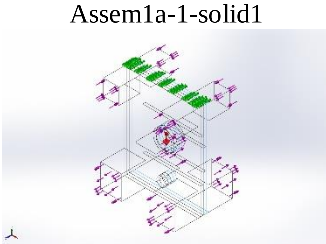
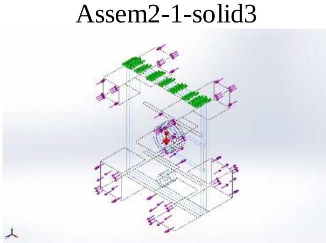
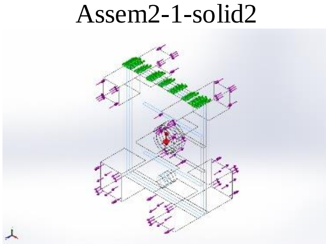
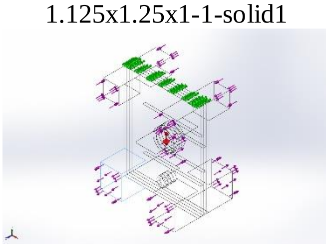
Model Information

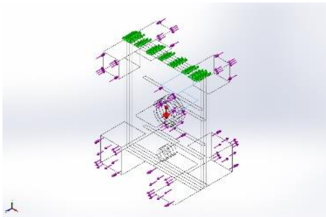
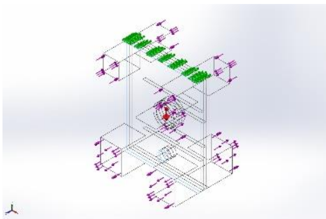
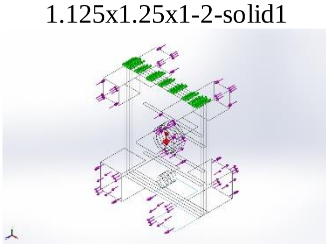
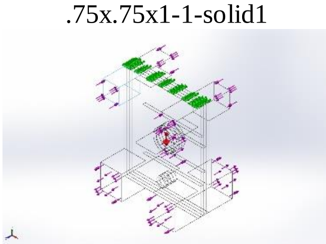


Model name: modified complete joint
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
1.125x1.25x1-2-solid1 	Solid Body	**Mass:0.162808 kg Volume:2.07399e-005 m^3 Density:7850 kg/m^3 Weight:1.59552 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\Modified male joint.SLDPRT** Nov 08 11:13:59 2016
Assem1a-1-solid2 	Solid Body	**Mass:0.0221008 kg Volume:2.81539e-006 m^3 Density:7850 kg/m^3 Weight:0.216588 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\Modified male joint.SLDPRT** Nov 08 11:13:59 2016
.75x.75x1-2-solid1 	Solid Body	**Mass:0.0723591 kg Volume:9.21772e-006 m^3 Density:7850 kg/m^3 Weight:0.709119 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\Modified male joint.SLDPRT** Nov 08 11:13:59 2016
1.125x1.25x1-1-solid1	Solid Body	**Mass:0.162808 kg Volume:2.07399e-005 m^3**	**\\EGRSHARES\Homes\NAU-**

		**Density:7850 kg/m^3** **Weight:1.59552 N**	**STUDENTS\sjh282\Desktop\Joint\Modified male joint.SLDPRT** Nov 08 11:13:59 2016
Assem1a-1-solid3 	Solid Body	**Mass:0.0758099 kg** **Volume:9.65731e-006 m^3** **Density:7850 kg/m^3** **Weight:0.742937 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\Modified male joint.SLDPRT** Nov 08 11:13:59 2016
.75x.75x1-1-solid1 	Solid Body	**Mass:0.0723591 kg** **Volume:9.21772e-006 m^3** **Density:7850 kg/m^3** **Weight:0.709119 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\Modified male joint.SLDPRT** Nov 08 11:13:59 2016
Assem1a-1-solid1 	Solid Body	**Mass:0.238211 kg** **Volume:3.03453e-005 m^3** **Density:7850 kg/m^3** **Weight:2.33446 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\Modified male joint.SLDPRT** Nov 08 11:13:59 2016
Assem2-1-solid3 	Solid Body	**Mass:0.216413 kg** **Volume:2.75685e-005 m^3** **Density:7850 kg/m^3** **Weight:2.12085 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\modified feamale joint.SLDPRT** Nov 08 11:18:57 2016
Assem2-1-solid2 	Solid Body	**Mass:0.162401 kg** **Volume:2.0688e-005 m^3** **Density:7850 kg/m^3** **Weight:1.59153 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\modified feamale joint.SLDPRT** Nov 08 11:18:57 2016
1.125x1.25x1-1-solid1 	Solid Body	**Mass:0.162808 kg** **Volume:2.07399e-005 m^3** **Density:7850 kg/m^3** **Weight:1.59552 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\modified feamale joint.SLDPRT** Nov 08 11:18:57 2016

.75x.75x1-2-solid1 	Solid Body	**Mass:0.0723591 kg Volume:9.21772e-006 m^3 Density:7850 kg/m^3 Weight:0.709119 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\modified feamale joint.SLDPRT** Nov 08 11:18:57 2016
Assem2-1-solid1 	Solid Body	**Mass:0.25084 kg Volume:3.19541e-005 m^3 Density:7850 kg/m^3 Weight:2.45823 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\modified feamale joint.SLDPRT** Nov 08 11:18:57 2016
1.125x1.25x1-2-solid1 	Solid Body	**Mass:0.162808 kg Volume:2.07399e-005 m^3 Density:7850 kg/m^3 Weight:1.59552 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\modified feamale joint.SLDPRT** Nov 08 11:18:57 2016
.75x.75x1-1-solid1 	Solid Body	**Mass:0.0723591 kg Volume:9.21772e-006 m^3 Density:7850 kg/m^3 Weight:0.709119 N**	**\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint\modified feamale joint.SLDPRT** Nov 08 11:18:57 2016

Study Properties

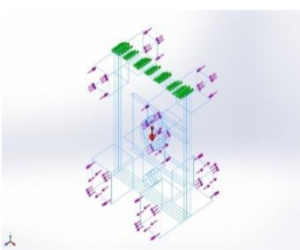
Study name	Static 4
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic

Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (\\EGRSHARES\Homes\NAU-STUDENTS\sjh282\Desktop\Joint)

Units

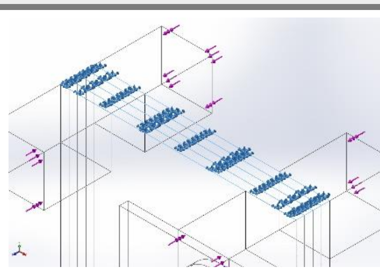
Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

Model Reference	Properties	Components
	**Name:** AISI 4130 Steel annealed at 865C **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 4.6e+008 N/m^2 **Tensile strength:** 5.6e+008 N/m^2 **Elastic modulus:** 2.05e+011 N/m^2 **Poisson's ratio:** 0.285 **Mass density:** 7850 kg/m^3 **Shear modulus:** 8e+010 N/m^2	SolidBody 1(1.125x1.25x1-2-solid1)(Modified male joint-1), SolidBody 2(Assem1a-1-solid2)(Modified male joint-1), SolidBody 3(.75x.75x1-2-solid1)(Modified male joint-1), SolidBody 4(1.125x1.25x1-1-solid1)(Modified male joint-1), SolidBody 5(Assem1a-1-solid3)(Modified male joint-1), SolidBody 6(.75x.75x1-1-solid1)(Modified male joint-1), SolidBody 7(Assem1a-1-solid1)(Modified male joint-1), SolidBody 1(Assem2-1-solid3)(modified feamale joint-1), SolidBody 2(Assem2-1-solid2)(modified feamale joint-1), SolidBody 3(1.125x1.25x1-1-solid1)(modified feamale joint-1), SolidBody 4(.75x.75x1-2-solid1)(modified feamale joint-1), SolidBody 5(Assem2-1-solid1)(modified feamale joint-1), SolidBody 6(1.125x1.25x1-2-solid1)(modified feamale joint-1), SolidBody 7(.75x.75x1-1-solid1)(modified feamale joint-1)

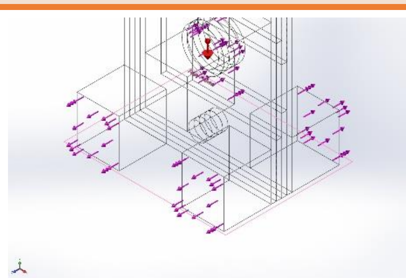
Curve Data:N/A

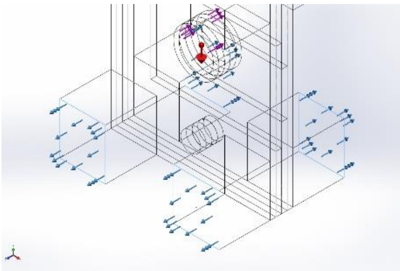
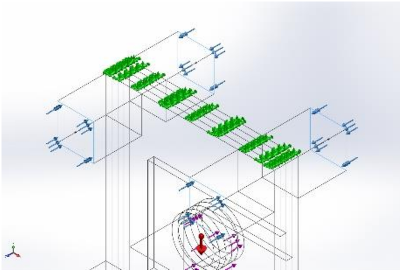
Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 4 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-1.0252e-005	18.7028	-0.000277519	18.7028
Reaction Moment(N.m)	0	0	0	0

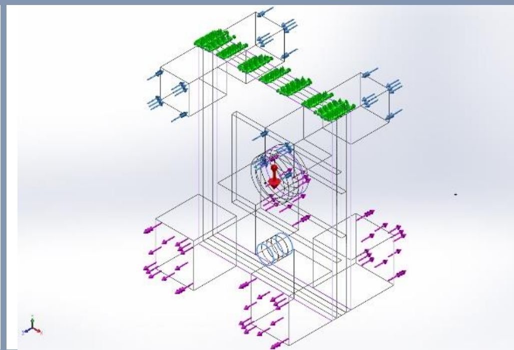
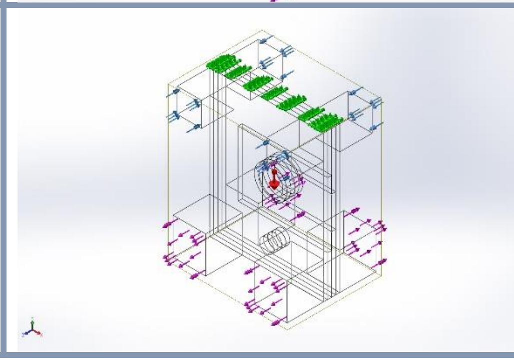
Load name	Load Image	Load Details
Gravity-1		**Reference:** Top Plane **Values:** 0 0 -9.81 **Units:** SI

Force-1		**Entities:** 4 face(s) **Type:** Apply normal force **Value:** -4500 N
Force-2		**Entities:** 4 face(s) **Type:** Apply normal force **Value:** 382.175 lbf

Connector Definitions

No Data

Contact Information

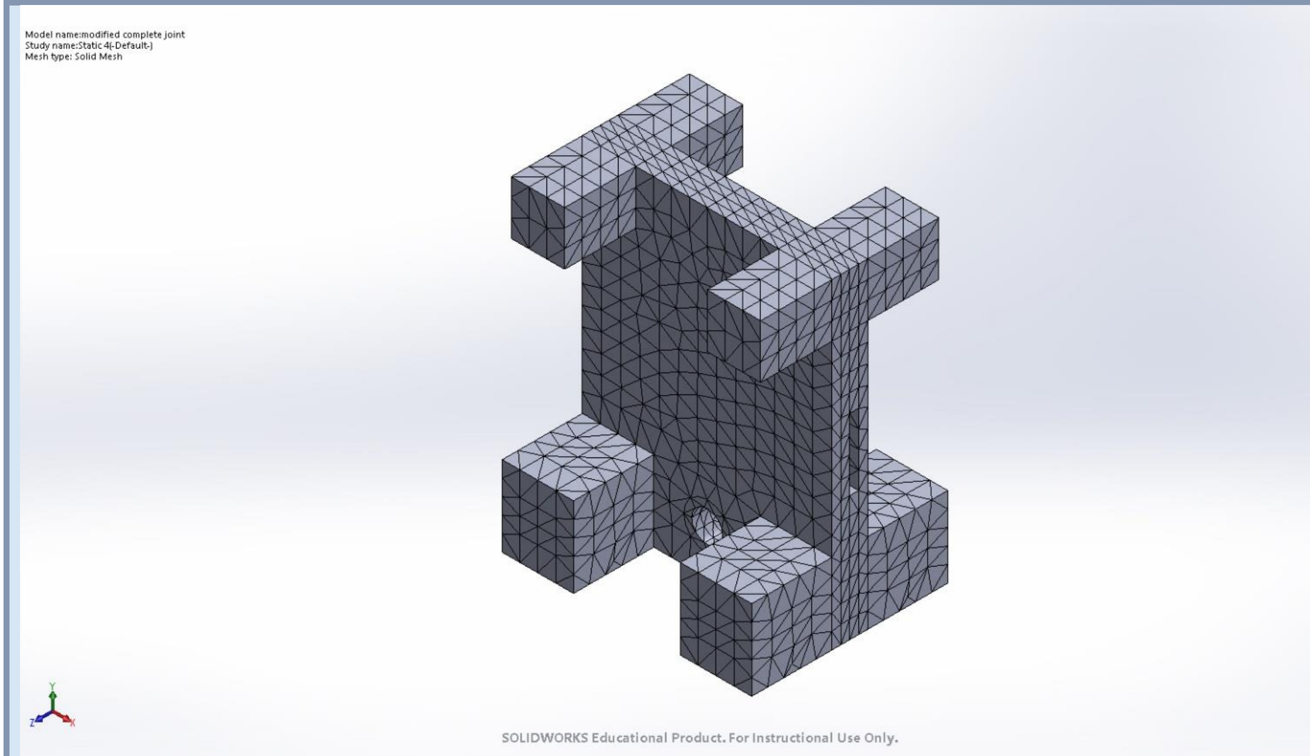
Contact	Contact Image	Contact Properties
Contact Set-1		**Type:** No Penetration contact pair **Entites:** 2 edge(s), 2 face(s) **Advanced:** Node to surface
Global Contact		**Type:** Bonded **Components:** 1 component(s) **Options:** Compatible mesh

Mesh information

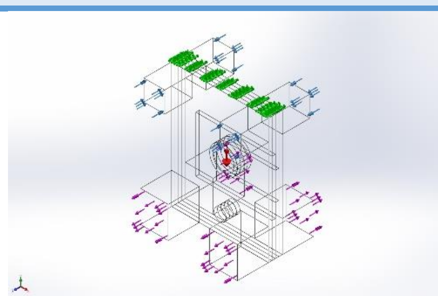
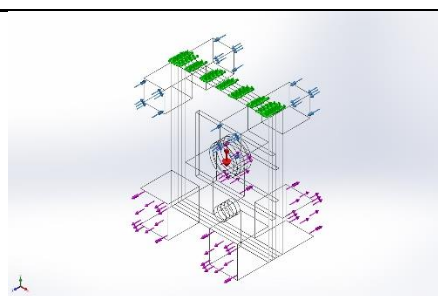
Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	0.266301 in
Tolerance	0.013315 in
Mesh Quality Plot	High
Remesh failed parts with incompatible mesh	Off

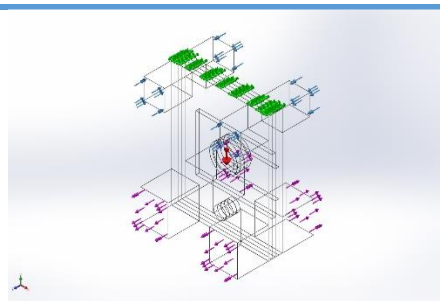
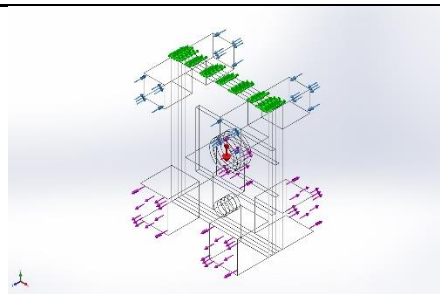
Mesh information - Details

Total Nodes	14663
Total Elements	8935
Maximum Aspect Ratio	8.0249
% of elements with Aspect Ratio < 3	91.7
% of elements with Aspect Ratio > 10	0
% of distorted elements(Jacobian)	0

Time to complete mesh(hh;mm;ss):	00:00:03
Computer name:	EGR113B-12
	

Sensor Details

Sensor name	Location	Sensor Details
Stress1		Value : Entities : Result :Stress Component :VON: von Mises Stress Criterion :Model Max Step Criterion : Across all Steps Step No.:1 Alert Value: NA
Measurement1		Value : Distance: 0.5in Entities : Result :Stress Component :VON: von Mises Stress Criterion :Model Max Step Criterion : Across all Steps Step No.:1 Alert Value: NA

Stress2		Value : Entities : Result :Stress Component :VON: von Mises Stress Criterion :Model Max Step Criterion : Across all Steps Step No.:1 Alert Value: NA
Stress3		Value : Entities : Result :Stress Component :VON: von Mises Stress Criterion :Model Max Step Criterion : Across all Steps Step No.:1 Alert Value: NA

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-1.0252e-005	18.7028	-0.000277519	18.7028

Reaction Moments

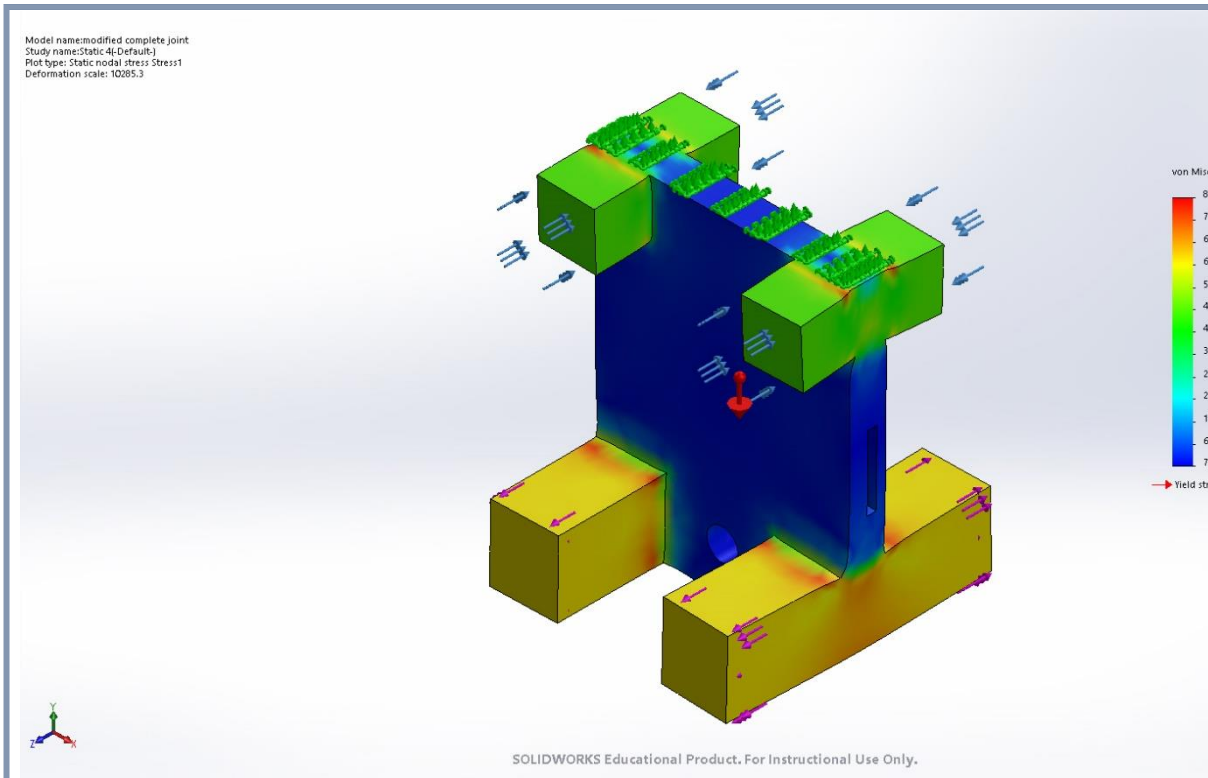
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

No Data

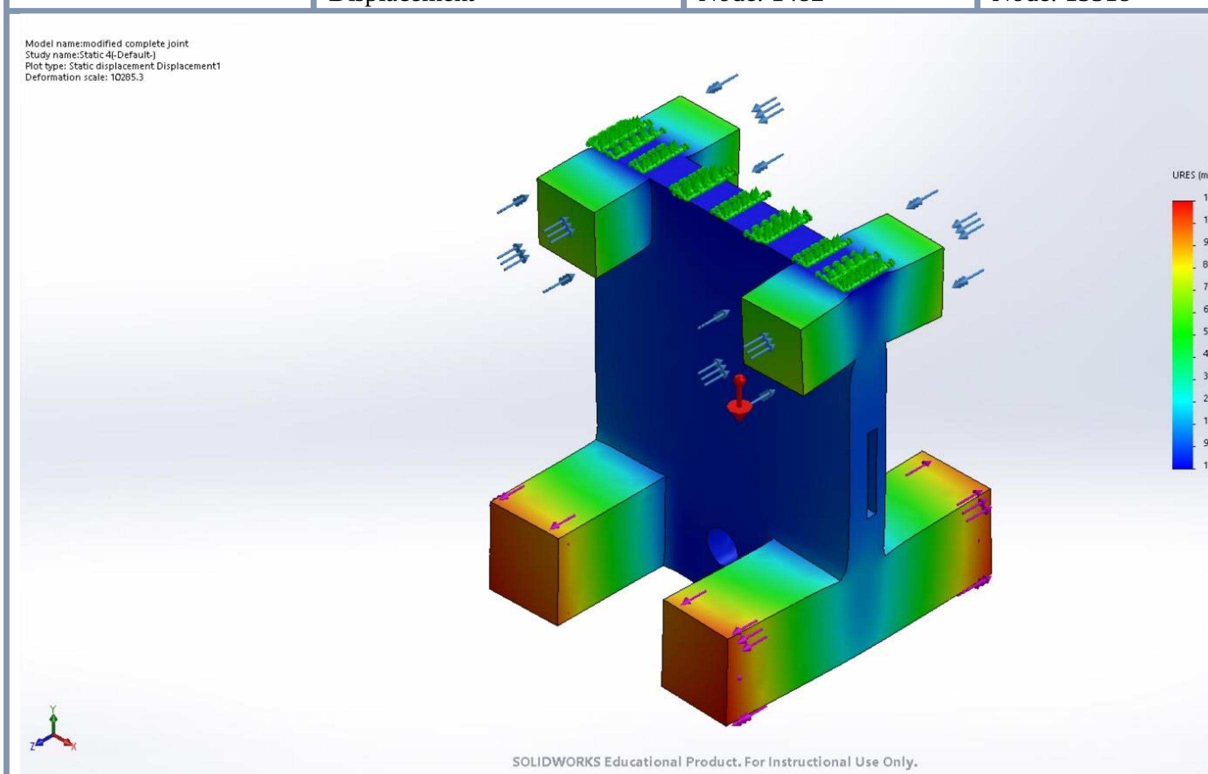
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	7.922e+003N/m^2 Node: 8088	8.087e+006N/m^2 Node: 899



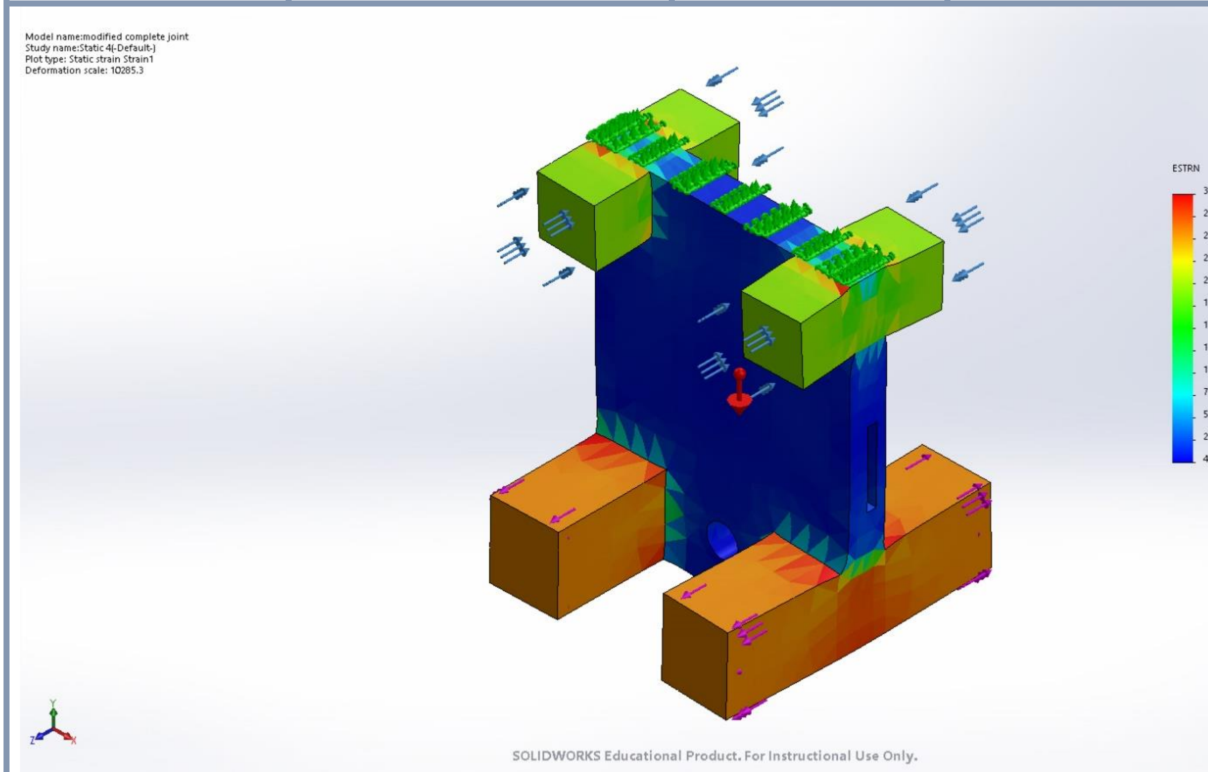
modified complete joint-Static 4-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+000mm Node: 1482	1.171e-003mm Node: 13318



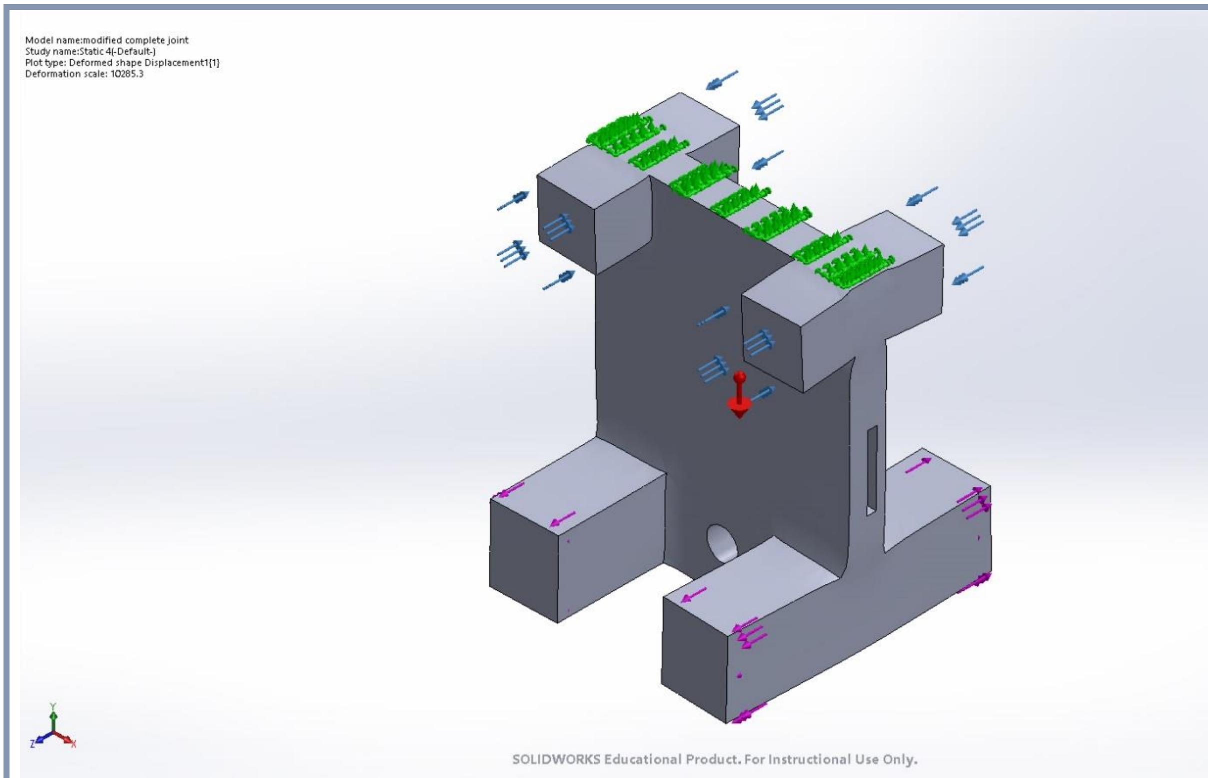
modified complete joint-Static 4-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	4.559e-008 Element: 7911	3.020e-005 Element: 6373



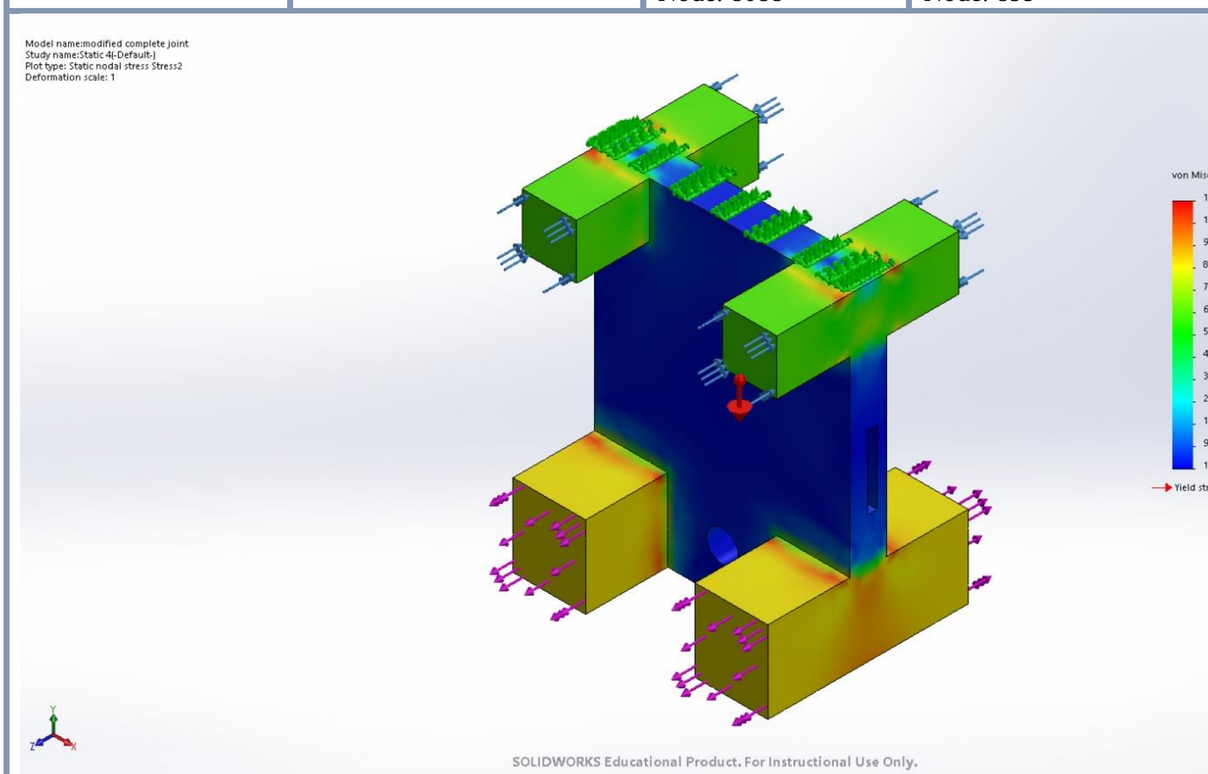
modified complete joint-Static 4-Strain-Strain1

Name	Type
Displacement1{1}	Deformed shape



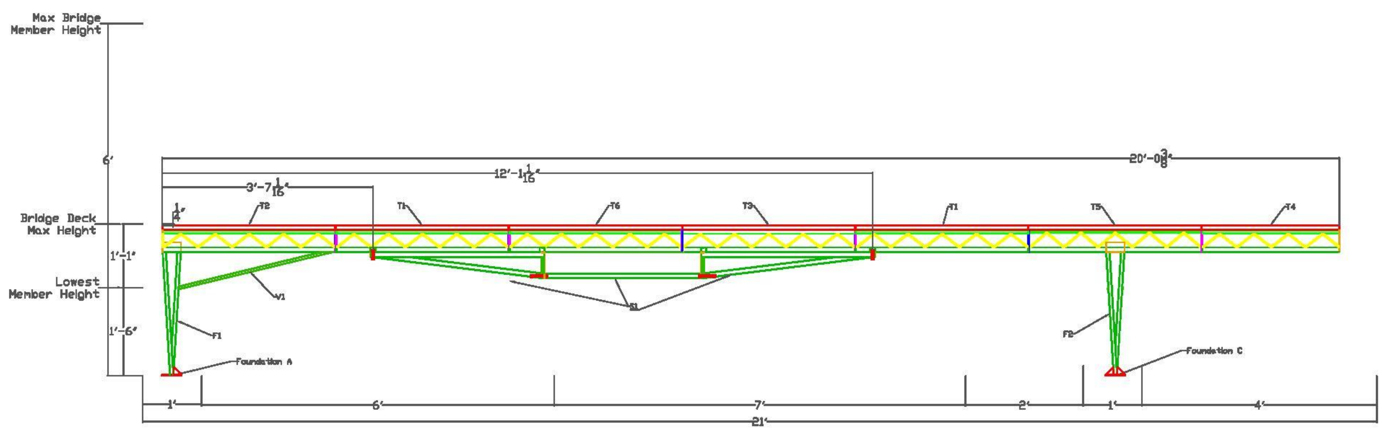
modified complete joint-Static 4-Displacement-Displacement1{1}

Name	Type	Min	Max
Stress2	VON: von Mises Stress	1.149e-003ksi Node: 8088	1.173e+000ksi Node: 899



modified complete joint-Static 4-Stress-Stress2

Appendix C – Construction Drawings



Elevation View

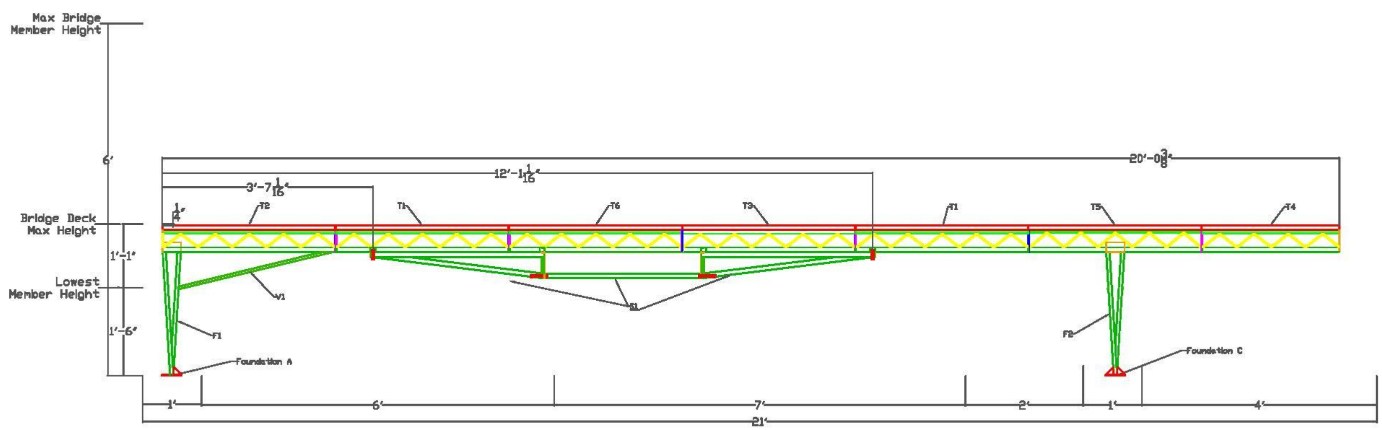
General Notes

No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 1



Elevation View

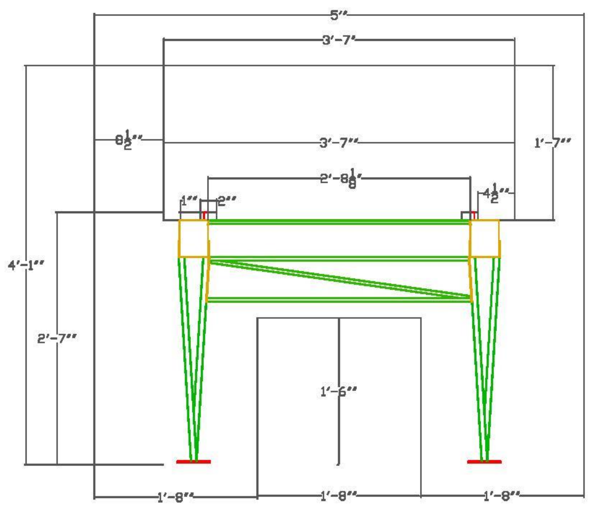
General Notes

No.	Revision/Issue	Date

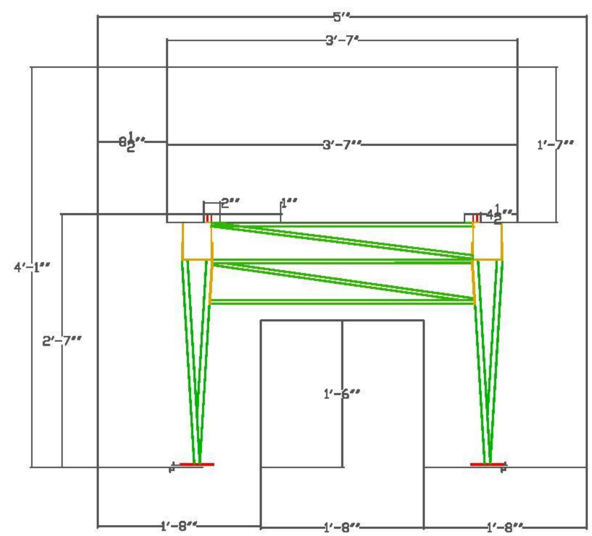
Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 1



End View From Foundation A
Some diagonal bracing is
excluded for clarity



End View From Foundation C
Some diagonal bracing is
excluded for clarity

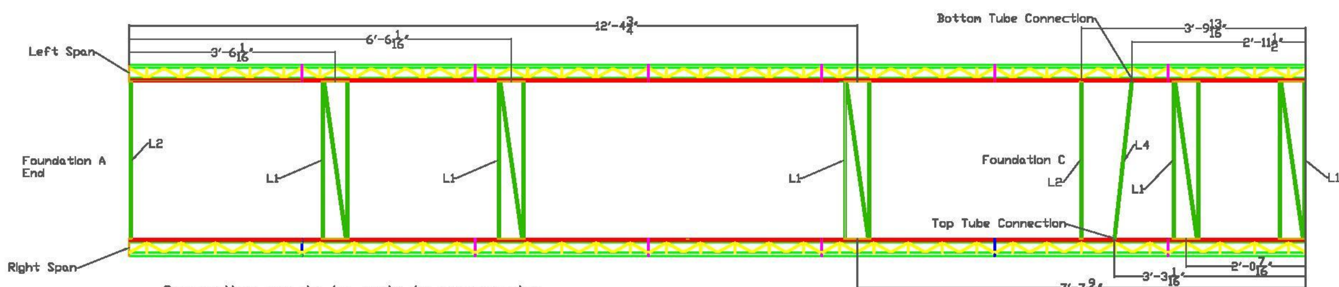
General Notes

No. Revision/Issue Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 2



Connection are to be made to compression members unless specifically noted otherwise

Plan View

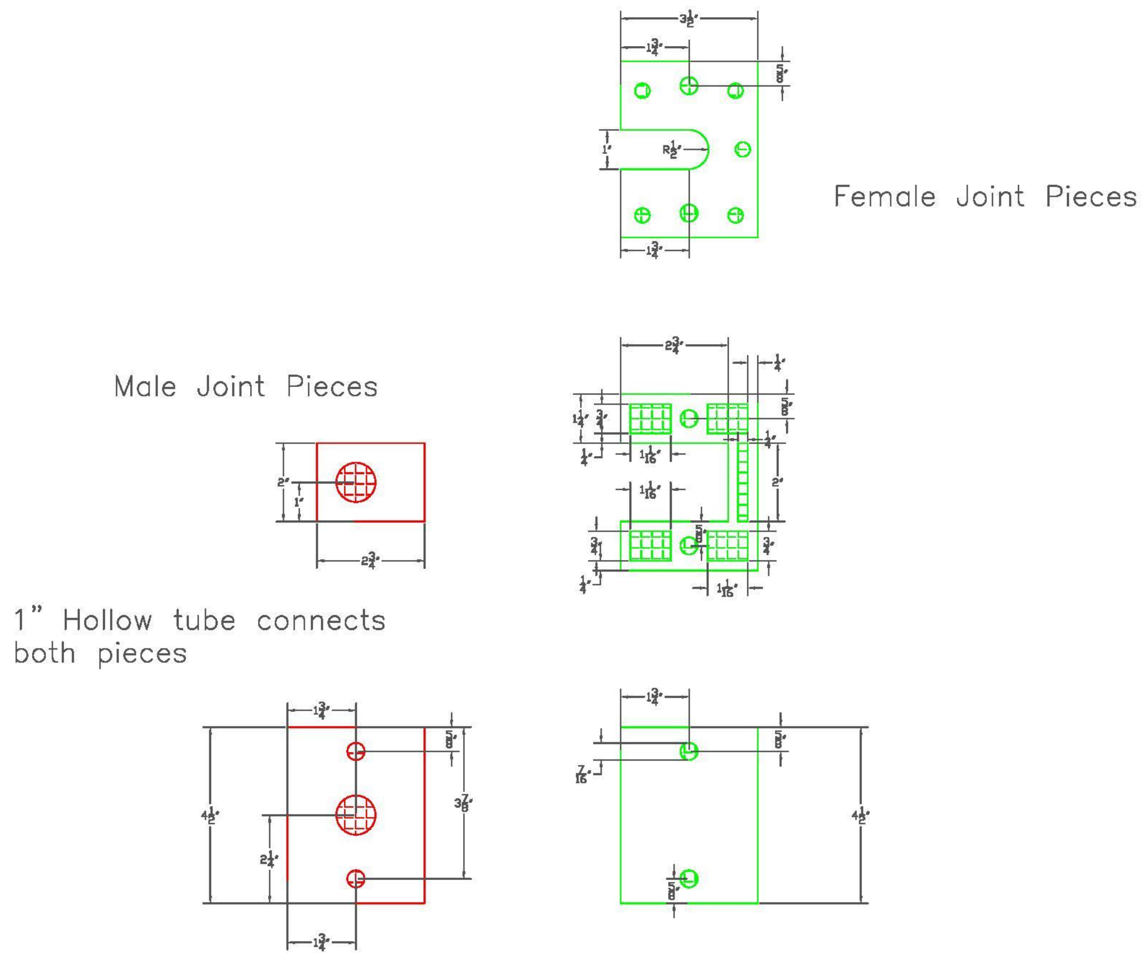
General Notes

No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 3



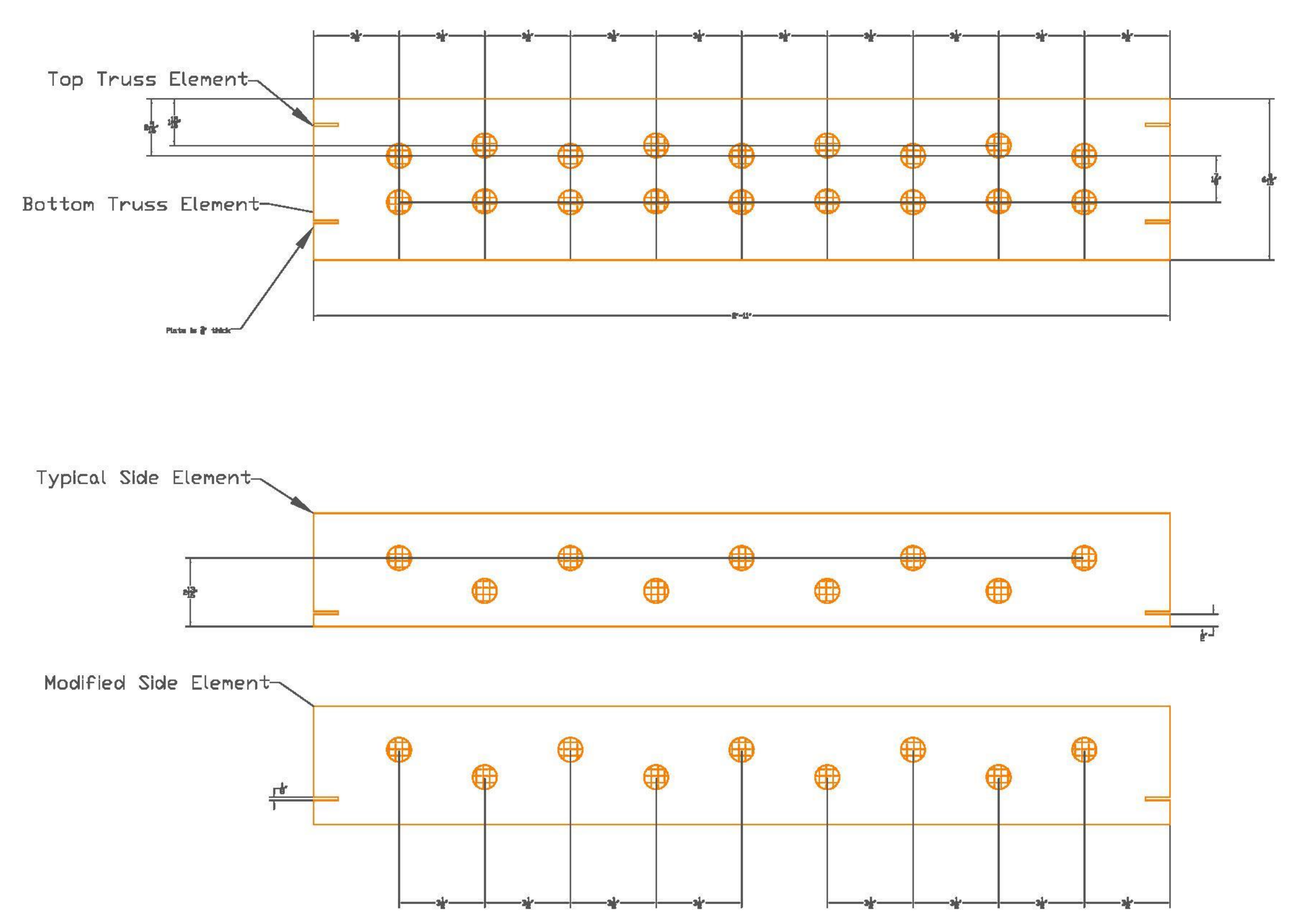
General Notes

No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 4



General Notes

No.	Revision/Issue	Date

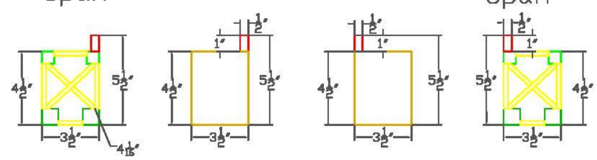
Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

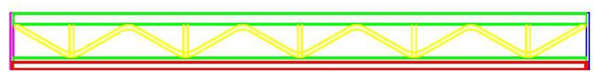
Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 5

Left Span

Right Span



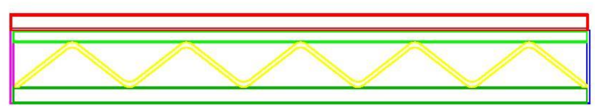
Cross Section



TOP

Refer to Page 2 of drawings for HSS 1"x½"x1/16" template

BOTTOM



PLAN

Typical Span Truss (T1)

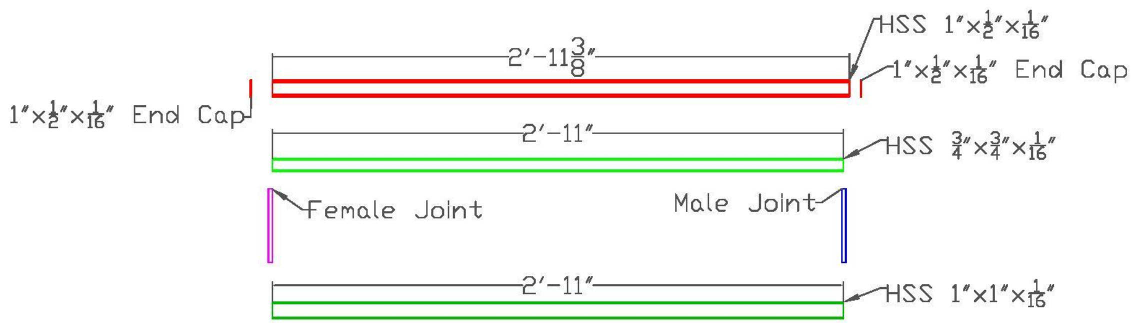
General Notes

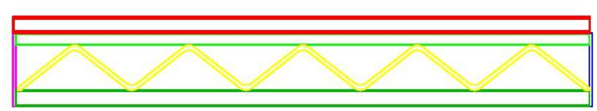
No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project	Sheet
Steel Bridge	6
Date: 2/5/2017	
Scale: As Noted	





PLAN

Typical Span Truss

<T1>

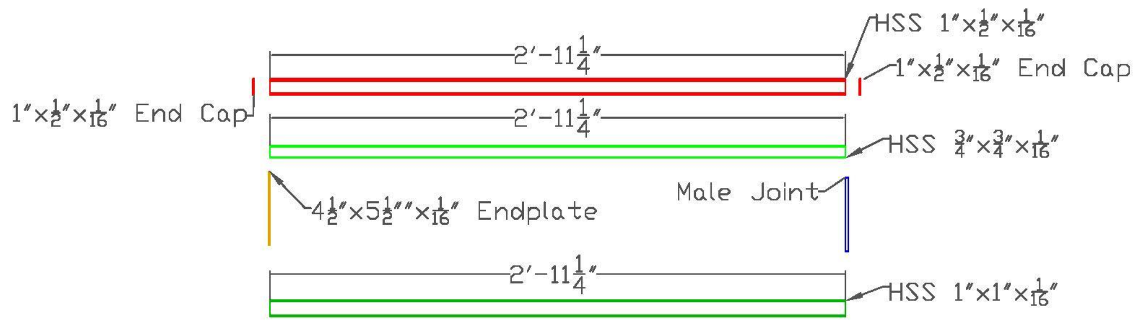
General Notes

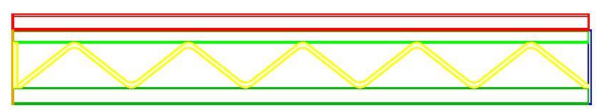
No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 7





Foundation A Truss (T2)
Typical Mini Truss Element
End (Modified)

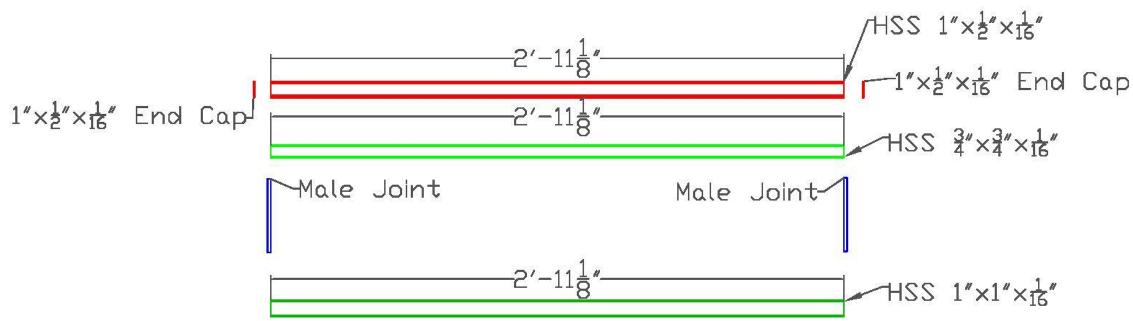
Project	Steel Bridge
Date	2/5/2017
Scale	As Noted
Sheet	8

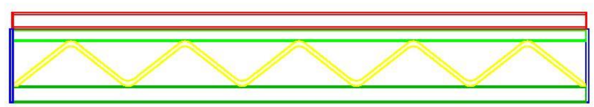
Project Name and Address: Steel Bridge AISC/ASCE NAU CENE

General Notes

No.	Revision/Issue	Date

Firm Name and Address





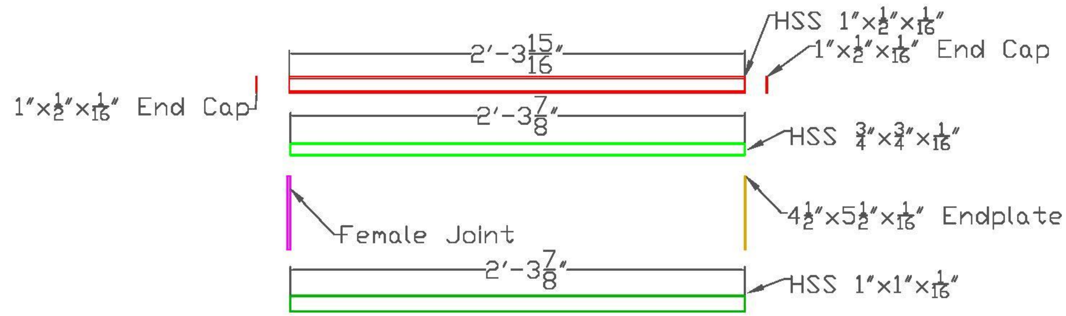
Center Truss (T3)
Typical Mini Truss
Element

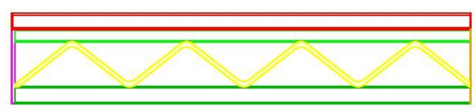
General Notes		
No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge	Sheet: 9
Date: 2/5/2017	
Scale: As Noted	





Cantilever Truss
(T4)
Typical Mini Truss
Element All Lengths
(Modified)

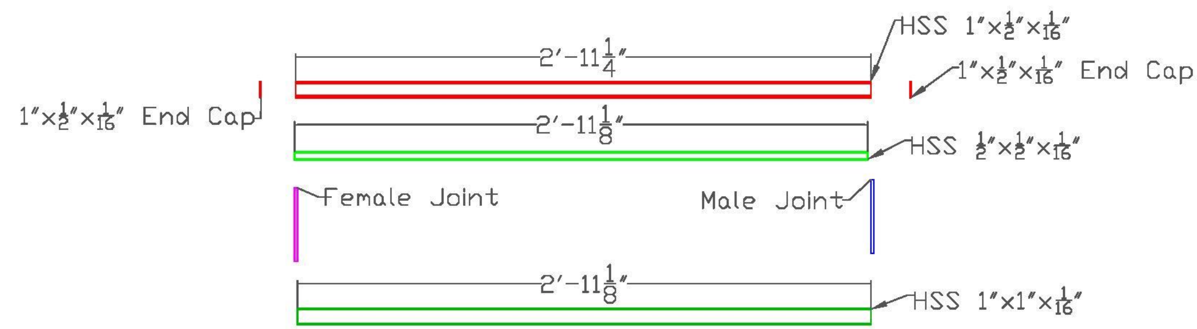
General Notes

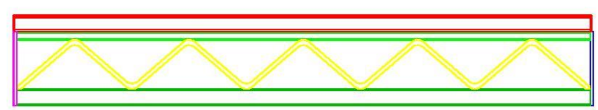
No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 10





Foundation C Truss (T5)
Foundation C Mini Truss
Side (Modified)
All others Typical

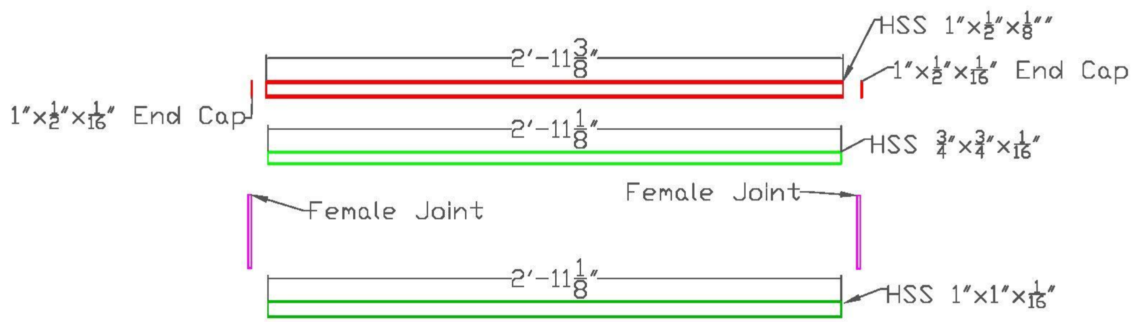
General Notes

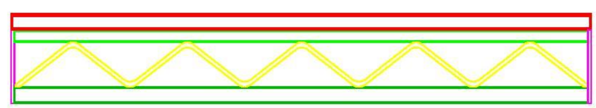
No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 11





Double Female Truss
(T6)
All mini truss componets
are standard sizes

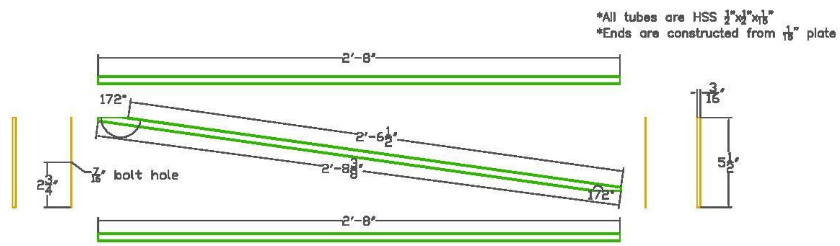
General Notes

No.	Revision/Issue	Date

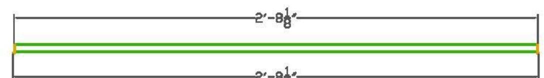
Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

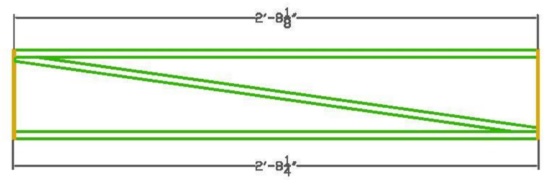
Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 12



Lateral Plate installed with plate lip toward ground



Plan



Elevation

Typical Lateral Bracing <L1>

General Notes

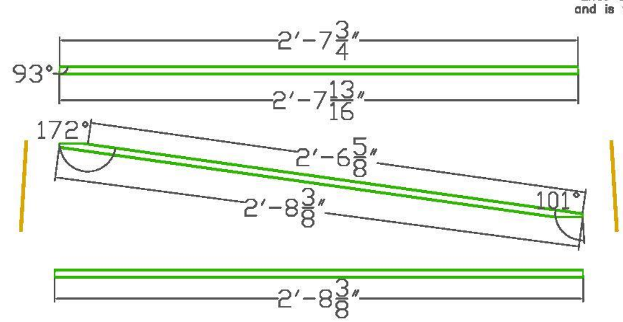
No.	Revision/Issue	Date

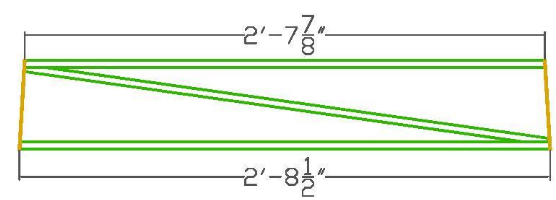
Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge	Sheet
Date: 2/5/2017	13
Scale: As Noted	

*All tubes are HSS $\frac{1}{2}$"x$\frac{1}{2}$"x$\frac{1}{16}$"
*Ends are constructed from $\frac{1}{16}$" plate, and is the same as L1 ends





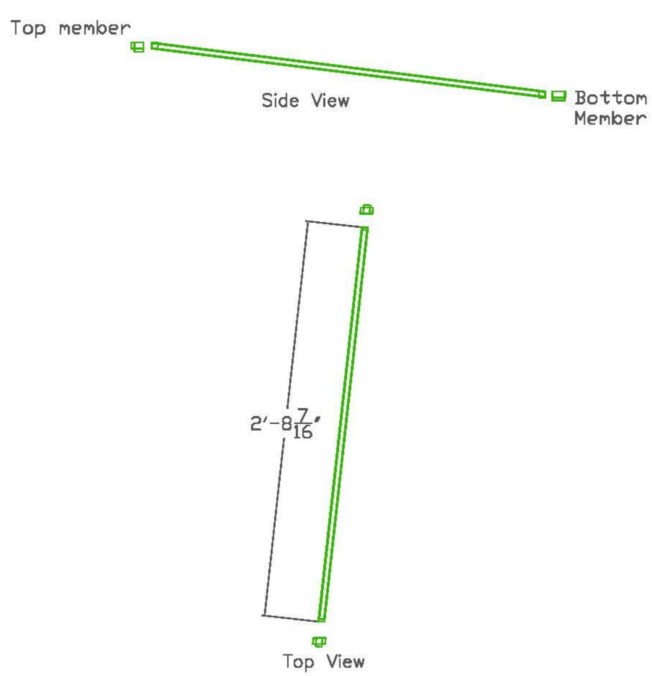
Foundation Lateral Bracing (L2)
Tapering upward to align with
vertical supports

General Notes		
No.	Revision/Issue	Date

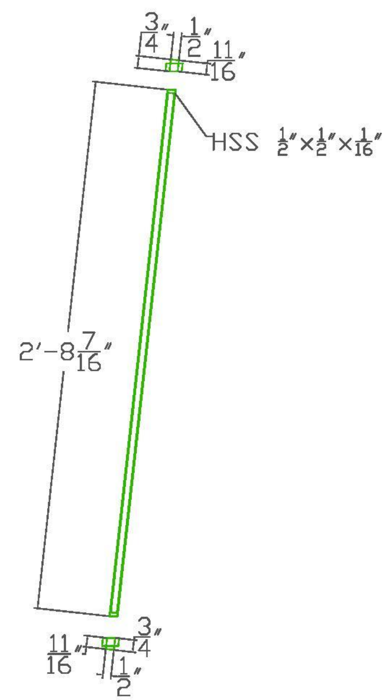
Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge	Sheet: 14
Date: 2/5/2017	
Scale: As Noted	



Lateral Bracing (L4)



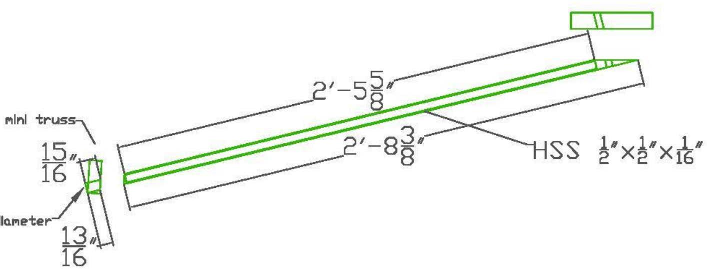
General Notes

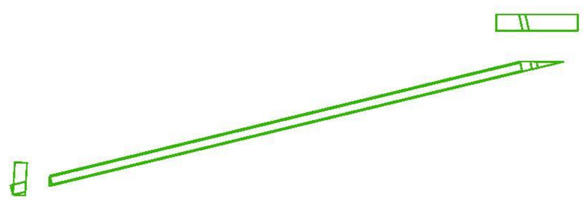
No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 15





Elevation View

Vertical Bracing (V1)

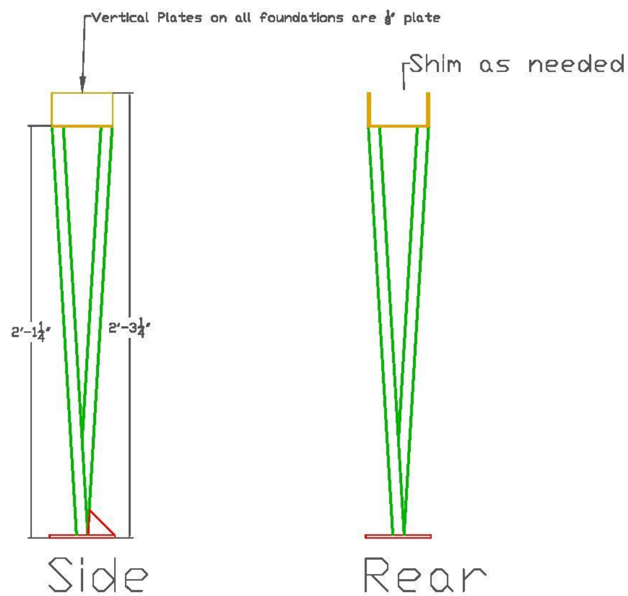
General Notes

No.	Revision/Issue	Date

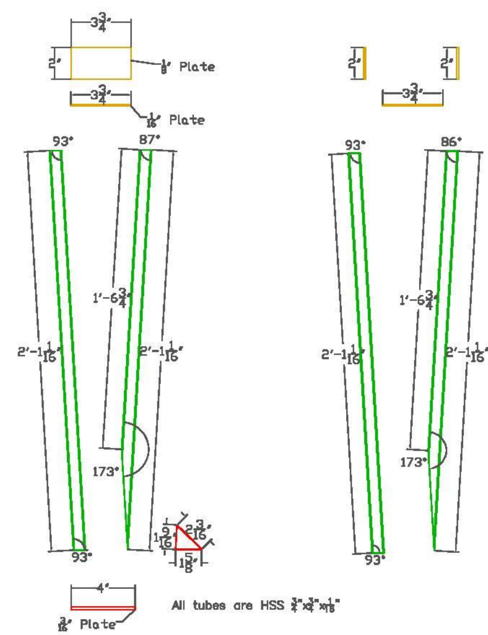
Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge
Date: 2/5/2017
Scale: As Noted
Sheet: 16

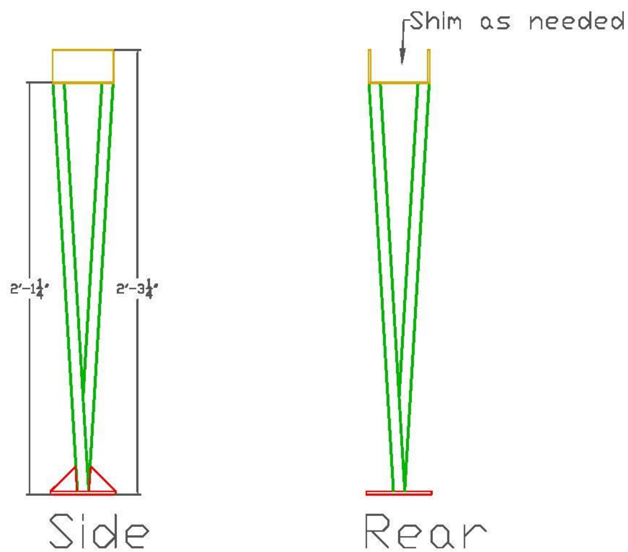


Foundation Support (F1)
Red gusset plate points toward main span



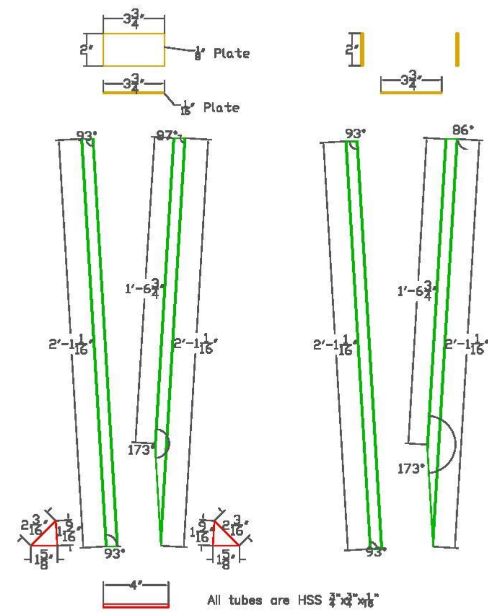
General Notes	
No.	Revision/Issue	Date

Firm Name and Address	
Project Name and Address	Steel Bridge AISC/ASCE NAU CENE
Project	Steel Bridge
Date	2/5/2017
Scale	As Noted
Sheet	17



Foundation Support (F2)

Red gusset plate pointing to both spans



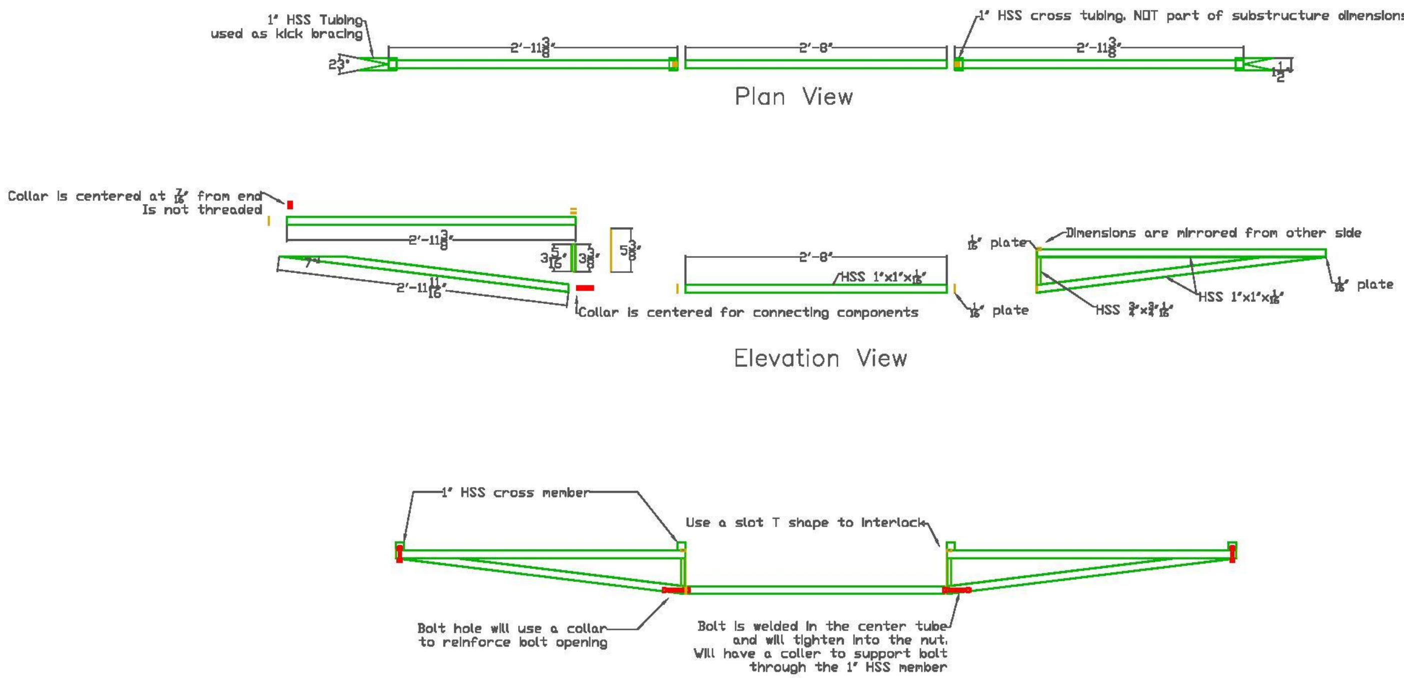
General Notes

No.	Revision/Issue	Date

Firm Name and Address

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge	Sheet: 18
Date: 2/5/2017	
Scale: As Noted	



Span Substructure (S1)
Bolt inspection holes and final bolt length are to be determined during mockup.

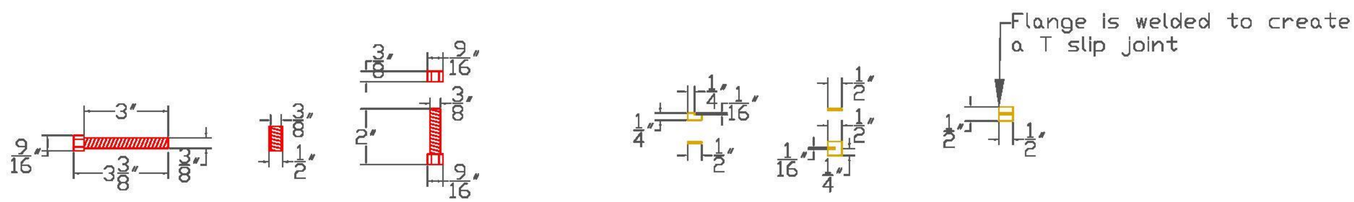
General Notes

No.	Revision/Issue	Date

Project Name and Address
Steel Bridge
AISC/ASCE
NAU
CENE

Project: Steel Bridge	Sheet: 19
Date: 2/5/2017	
Scale: As Noted	

Substructure Connection Details

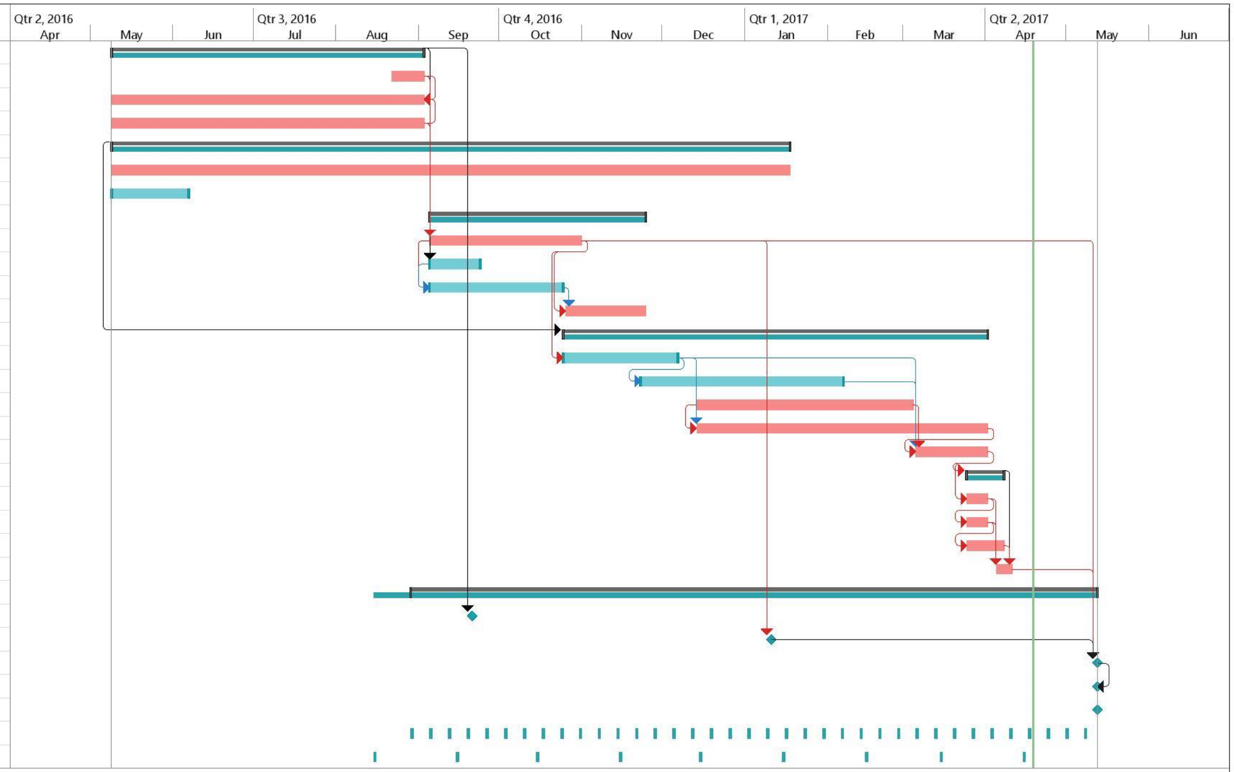


Steel Bridge
AISC/ASCE
NAU
CENE

Steel Bridge
2/5/2017
As Noted
20

Appendix D – Gantt Chart

ID	Name
1	**1.0 Research**
2	1.1 Competition Rules
3	1.2 Analysis Methods
4	1.3 Materials Research
5	**2.0 Fundraising**
6	2.2 Sponsorships
7	2.3 Go Fund Me
8	**3.0 Structural Analysis and Design**
9	3.1 RISA Model
10	3.2 Connection Design
11	3.3 Materials Analysis
12	3.4 Fabrication Plans
13	**4.0 Fabrication**
14	4.1 Construction Drawings
15	4.2 Jig Creation
16	4.3 Fabricate Components
17	4.4 Finalize Welding and Fabrication
18	4.5 Inventory of Bridge Components and Final Layout
19	**5.0 Construction**
20	5.1 Construction Methods
21	5.2 Method Selection
22	5.3 Construction Practice
23	**6.0 PSWC**
24	**7.0 Project Management**
25	7.1 Project Schedule
26	7.2 50% Design Report
27	7.3 Final Design Report
28	7.4 Final Presentation
29	7.5 Website
30	7.6 Team Meeings
68	7.7 Client Communications



Task
Split
Milestone
Slippage
Summary
Project Summary
Rolled Up Critical
Rolled Up Critical Split
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Critical
Critical Split
Progress

Appendix E – Footing Decision Matrix

		Footing AC		Footing AB	
	Weight %	Raw Score	Weighted Score	Raw Score	Weighted Score
Cost	60%	1	0.6	9	5.4
Vertical Deflection	30%	3	0.9	9	2.7
Lateral Deflection	10%	9	0.9	3	0.3
Sum	**100%**	**13**	**2.4**	**21**	**8.4**

Appendix F – Upper Chord Decision Matrix

		No - Upper Chord		Upper Chord	
	Weight %	Raw Score	Weighted Score	Raw Score	Weighted Score
Aesthetics	10%	3	0.3	9	0.9
Construction Time	35%	9	3.15	1	0.35
Weight	35%	9	3.15	3	1.05
Strength	20%	3	0.6	9	1.8
Total	**100%**	**24**	**7.2**	**22**	**4.1**

Appendix G – Bridge Member Decision Matrix

		4x6 HSS Tubing		2D Mini-Truss		Triangular 3D Mini-Truss		Square 3D Mini-Truss		Rectangular 3D Mini-Truss	
	Weight %	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Deflection	75%	1	0.75	2	1.5	4	3	3	2.25	5	3.75
Weight	25%	5	1.25	4	1	3	1	2	0.75	1	1.25
Total	**100%**	**6**	**2**	**6**	**2.5**	**7**	**4**	**5**	**3**	**6**	**5**

Appendix H – Deflection Reduction Decision Matrix

		Substructure		Increase Member Size		Increase Member Thickness	
	Weight %	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Deflection	50%	9	4.5	3	1.5	9	4.5
Weight	50%	9	4.5	1	0.5	1	0.5
Total	**100%**	**18**	**9**	**4**	**2**	**10**	**5**

Appendix I – Connection Decision Matrix

		Gusset Plate		Slip Connection	
	Weight %	Raw Score	Weighted Score	Raw Score	Weighted Score
Fabrication Ease	5%	9	0.45	3	0.15
Construction Time	65%	1	0.65	9	5.85
Weight	30%	9	2.7	1	0.3
Total	**100%**	**19**	**3.8**	**13**	**6.3**