NORTHERN ARIZONA UNIVERSITY

Steel Bridge Team Project: Final Report

CENE 486C-001

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List of Abbreviations

Table 1: Variables for Bolt Strength

Table of Variables for Bolt Strength	
Symbol	**Definition**
Ab	The cross-sectional area of the bolt (in^2)
Fnt	nominal tensile strength (KSI)
ϕ	safety factor, .75
Fu	Yield stress (KSI)
Lc	clear distance in direction of force between the edge of the hole and the end of material (in)
Fnv	nominal shear strength of bolts

Table 2: Variables for Buckling

Table of Variables for Buckling	
Symbol	**Definition**
I	moment of inertia (in^4)
A	cross-sectional area (in^2)
K	effective length factor
L	The complete length of the connection
E	modulus of elasticity of steel, 29000 KSI
Fy	yield stress of the steel
Ag	Gross area as it is thickness*Height of the plate
ϕ	safety factor, 0.9

Table 3: Variables for Tensile Yield

Table of Variables for Tensile Yield	
Symbol	**Definition**
Ae	net area (In^2)
d	diameter of the screw (in)
ϕ	safety factor, 0.75

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Acknowledgments

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1.0 Project Introduction

1.1 Project Purpose

This project aims to design a 1:10 scale model of a hypothetical wildlife bridge to be judged at the regional Student Steel Bridge Competition (SSBC) on April 16th, 2022. This project will entail using various design and analysis methods to design and construct a functional bridge that can support a defined amount of loading and meet the specifications defined by the competition rules and requirements. The final design will be graded according to various criteria outlined within the provided competition guidelines and ranked to determine a winner for the 2022 Student Steel Bridge Competition.

1.2 Project Background

1.2.1 Competition Details

Arizona falls within the Intermountain Southwest Region for the competition, and therefore the team will be competing in the regional competition located in Las Vegas, Nevada. The competition will take place on April 16th, 2022. Final products from each participating team will be submitted and graded based on performance in various categories as outlined below. The teams with the highest collective score in all the categories will place the highest in the regional competition. This competition is sponsored by both AISC and ASCE.

1.2.2 Scoring

1.2.2.1 Aesthetics

The competition will have scoring based on the aesthetics of the bridge in terms of its appearance, balance, and proportion, including how the bridge is constructed. Another criterion of the aesthetics is the poster for the bridge and will be judged on what the poster has on it, such as the classification of the bridge and why a design was chosen, the name of the school presented, scaled dimension of the bridge, analysis method explanation, free body diagram that shows the performance of the stringers, shear and moment diagrams for the free body diagrams, use of Accelerated Bridge Construction (ABC), acknowledgment of those who have helped with the bridge construction, planning, and fabrication.

1.2.2.2 Construction Speed

The speed of the construction will be a factor in determining the overall performance of the bridge and how fast the construction can be done. The fastest overall time in the safest manner will score the highest and give an advantage in the competition.

1.2.2.3 Lightness

The lightness of the bridge will be judged based on the overall weight on the bridge and the one that weighs the lightest will be the one that scores the highest in the category.

1.2.2.4 Stiffness

The stiffness will be judged based on the lowest overall aggregate deflection due to the loading in the competition and will be given the highest score for the competition for this category.

1.2.2.5 Construction Economy

This category will judge a team based on the cost of their respective bridge and the lowest costing successful bridge will receive the highest score for that category.

1.2.2.6 Structural Efficiency

Structural efficiency is scored based on the formulas outlined in Student Steel Bridge Competition 2022 Rules section 6.2.6. Then the steel bridge team with the lowest score will win this category.

1.2.2.7 Overall Performance

The way that overall performance is scored is the judges will take the score of construction cost and structural cost and add them together. The steel bridge team that receives the lowest score will win this category.

2.0 Bridge Type and Design

The bridge was designed based on the provided SSBC guidelines and requires the bridge to be a cantilever bridge. The team used the software RISA to conduct the main design and perform the load testing to ensure the bridge works and is within the guidelines of the SSBC rules. A cantilever bridge is a bridge that is fixed to one area meaning it only has support from one side and is meant to sustain all the loading through those supports and the members of the bridge themselves. The bridge must withstand lateral and vertical loading combinations, mentioned below in Section 3.2, per the SSBC guidelines. Having the right member thickness and ensuring the members are in the right places helps with the loading that the bridge will endure, therefore limiting the deflection to allowable standards. To not get penalized, the bridge itself must weigh less than or equal to three hundred pounds.

According to the SSBC guidelines, the bridge must have parts building and sustaining it below the actual bridge itself so that animals cannot damage it by hitting it. It must also be a cantilever bridge with all necessary parts out of the reach of the wildlife. [1] This then meant that the selection of the type of bridge and its corresponding materials were limited. With the collaboration of our Technical Advisor, Sabrina Ballard, we decided that going with a truss design for our bridge would benefit us the most. This is because truss bridges utilize multiple triangles throughout their length between the top and bottom chords to ensure that the loading is distributed evenly to various members. Truss bridges are also stronger because they have a triangle design. Multiple different ideas were being used in the development of the bridge drafting when consulting with the team and our T.A., including making the diagonal supports crossed members so that they could carry the loading combinations seen in Section 3.2. This, however, was not used as it would increase the weight of the bridge to way over the 300-pound limit as per the guidelines. [1] As a result, the team decided to stick with the singular diagonal support members.

The triangles in a truss bridge have diagonal members that go from the interconnected bottom to the next in place interconnected top, which repeats in different directions, as shown below in Figure 1. Figure 1 is a Pratt Truss design that has diagonal members throughout the bridge, which connect the interconnected bottom connections to the next interconnected top connections, which then swap until it has met the bridge's end.

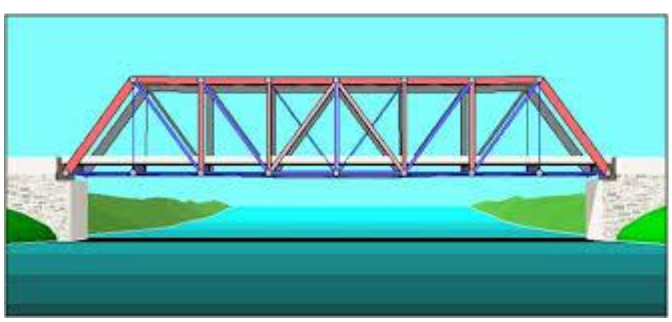

Figure 1: Pratt Truss design [2]

This design will be useful for dealing with the lateral and loading combinations that may be used when competing in the competition. This specific design using the diagonal members will help ease the loading and stress of the potential loads applied to the bridge by allowing more room for the stress and loading to occupy instead of just two or three members instead of it being simply too much and causing the bridge to fail. However, this did add more weight to the bridge as more members mean more weight. The final weight of the bridge is 238.93 pounds.

3.0 RISA 3D

3.1 Computer Modeling

The team used the computer software RISA to design and evaluate the loading that the bridge may endure at the competition. By adhering to the rules of the competition the bridge must be able to withstand the loads that the standards demand, the bridge needs to be able to withstand an amount necessary, which is seen below in Section 3.2. RISA solves for the self-weight and the deflections of the loading combinations that are inputted into the software. RISA also solves for Axial Tension and Compression, Flexural Analysis, Shear Analysis, Bending and Axial Interaction, and Torsional Analysis. An example of these engineering values can be found in Appendix A. These were analyzed to make sure that the bridge will withstand the potential loadings, which are in Section 3.2.

The length of the bridge is approximately 20.9 feet with the width being thirty inches wide the lateral members being twenty-six inches and the two members on the end of the laterals being two inches each. The competition guidelines state that the bridge must be a cantilever, must be 20-21 feet in length, and cannot exceed three'-7" in width as shown in the description provided by the ASCE. The supports for the bridge are placed two feet- to four inches above the bottom of the bridge cantilever supports as stated in the rules and drawings provided for the competition. The clearance from the cantilever legs to the main section of the bridge is exactly 7.5 inches as stated in the rules of the competition. The excerpts for these rules and guidelines are in Appendix B. An example of how the cantilever should look was provided by SSBC and this can be found in Appendix C. About the end reactions of the members, those results in RISA can be found in Appendix D.

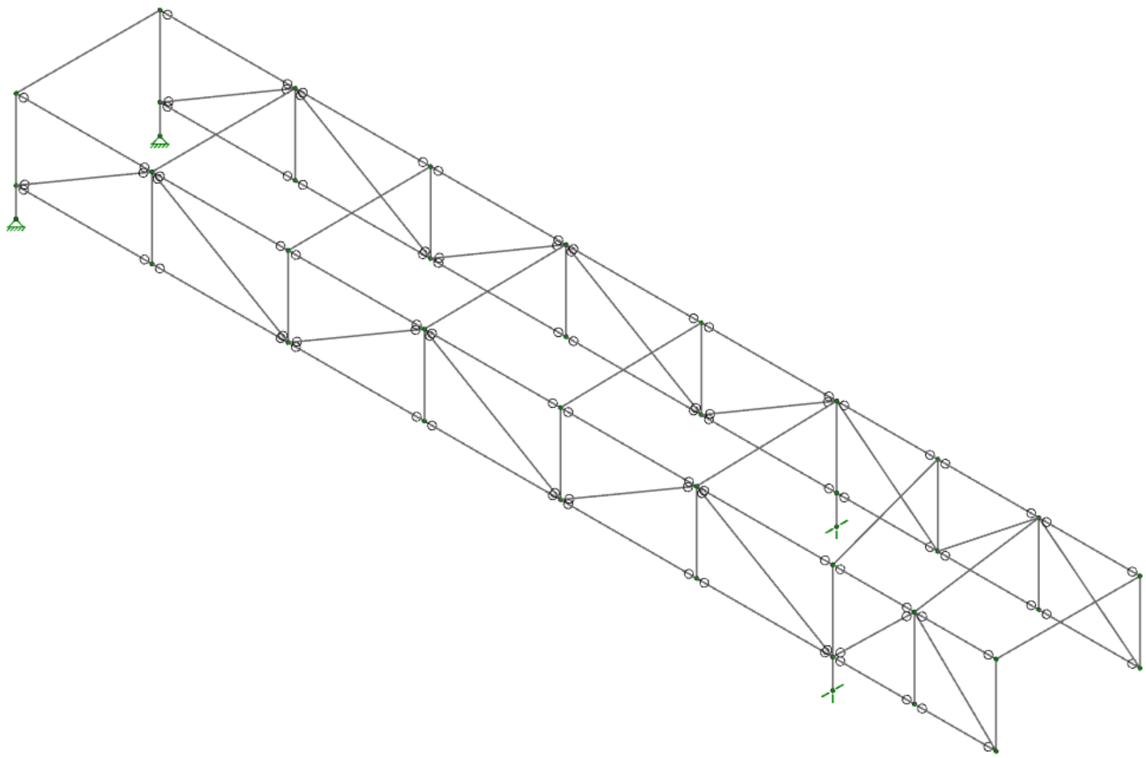

Figure 2: Initial Steel Bridge RISA Schematic

3.2 Load Combinations

The loading combinations came from the AISC SSBC 2022 rules. There are two lateral loading conditions and six vertical loading conditions. The first lateral loading condition deals with the back span. This has a 50-pound lateral load applied, where sway is measured on the north side of the bridge, centered on the decking unit positioned six feet away from the west end of the bridge. The second lateral loading condition deals with the cantilever itself. The decking from the lateral load test of the back span is left in place with the 75-pound weight moved to above the north side stringer.

Pertaining to the lateral loading, an example of how this will be analyzed can be seen in Appendix E. Below in Figure 3, the first lateral loading example of the 50-pound weight being applied is seen within RISA.

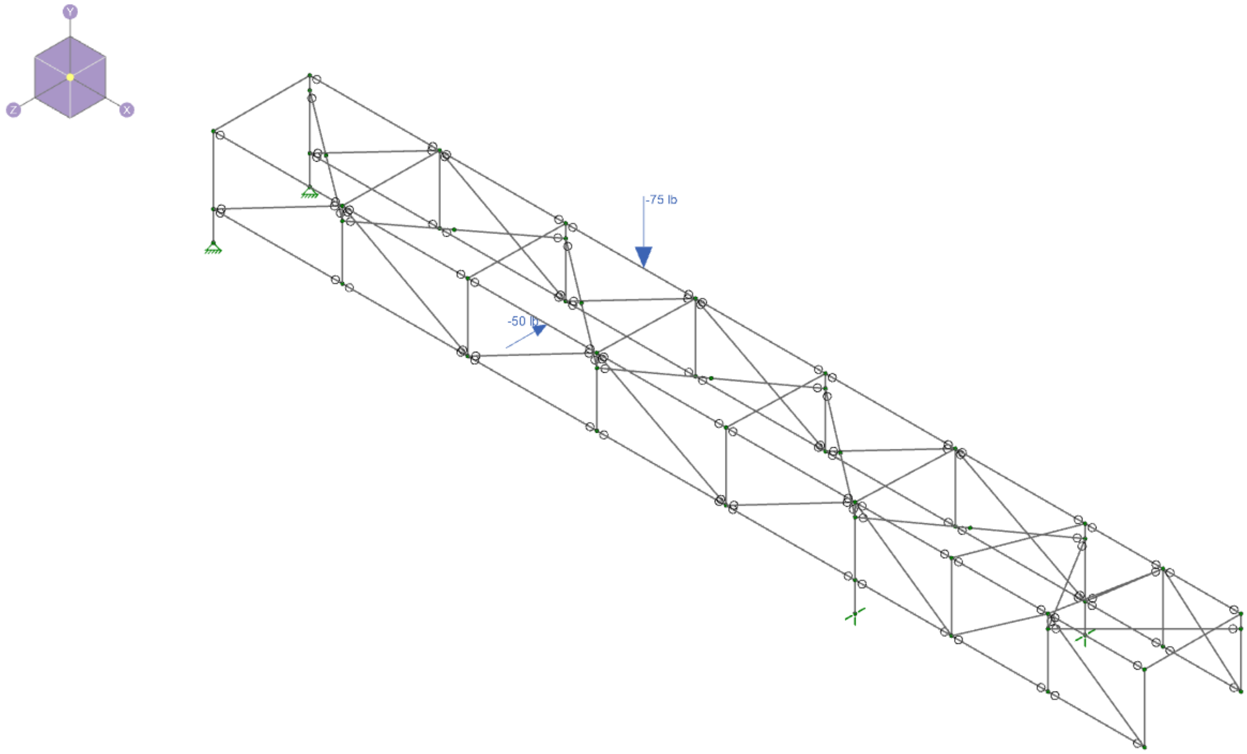

Figure 3: Lateral Load on RISA

This depicts the lateral load and how much the bridge will deflect based on the parameters of the material selection and what connections are chosen within RISA. For example, the members here are chosen to be pinned connections, which is why the deflection here is -0.153 inches in the y-direction and 0.115 inches in the z-direction. Vertical loading conditions are placed following Table 1 seen below, with the distance being determined by a dice roll at competitive on.

One decking unit is placed at a distance "L" from the west end of the bridge measured along the top of the north side stringer. The other decking unit is placed one inch from the east end of the bridge measured along the top of the south side stringer. The crew distributes one hundred pounds of preload on the decking unit positioned at "L" and fifty pounds of preload on the decking unit positioned on the cantilever. The preload is distributed uniformly, centered laterally on the decking unit, and positioned identically for each bridge. The crew places 1600 pounds of additional load on the decking unit at "L". The crew places 750 pounds of additional load on the decking unit on the cantilever. An example of how this will be analyzed can be seen below in Appendix F.

Table 4: Location Determination by dice roll provided by AISC [1]

N (dice roll)	L
1	4'6"
2	5'-6"
3	6'-0"
4	6'-6"
5	7'-0"

3.3 Material Selection

The material selected for this bridge was determined by researching different materials. The material that was decided for the bridge was A500 grade B steel for the members of the bridge and its connection plates. A500 Grade B steel has a yield stress of forty-six KSI and tensile stress of fifty-eight KSI. [2] This material was selected because of the lack of choices from the supplier, has good material characteristics, is exceptionally durable, and a large supply was able to be obtained from Page Steel. This material was selected for both the members and plates for the connections to make the steel order easier and allow for easier construction since the calculations can be done for the same material meaning no changes.

As advised by the technical advisor, the team is using A325 bolts for the construction of the bridge. The bridge will use these bolts for the connections to ensure that the bridge will not slip or tear out or break. The tensile strength of the bolts is 105 KSI and the yield strength is ninety-two KSI. The rupture and tear-out strength are used to determine how much the bolts and connections can take before it fails or rips out of the connections and members. As shown below in Figure 4, the highest load the bridge will sustain is approximately two Kips. This means that the tests need to be above 2 Kips, which all the tests are. The results are shown in Section 5 of this report, and passed the testing of 2 Kips, meaning the materials and bolts are the right choices for their bridge.

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4.0 Connection Design

The final designs for the connections and plates can be found in Appendix I. The method for determining the bridge connections and plates involves using the AISC manual to find the right equations to determine the size and what types of connections will be needed. AutoCAD will be used to draw the designs and see what size they need to be and how they fit into the design of the bridge.

The bridge has ninety-six total connections and has an array of different designs with thirteen different types of connections being used for the bridge with the connections being simple plates. The research for the connections was done by going to look at previous teams' connections and looking at actual real-world examples to see what is usually done and then plan from there.

As stated above, due to limitations from the supplier, the connections and plates are made from the same material as the bridge itself, being A500 grade B steel. The bolts for the connections are A325 bolts and will use washers and nuts to ensure extra support for the bolts, to ensure they will be loosened too easily. Our technical advisor advised us that A325 bolts are one of the best bolts for this type of construction of a miniature steel bridge.

The plates would all be the same thickness of an eighth of an inch. The connections will be simple plates that will go on the top and vertical back sides of the connecting members to ensure additional for tough connecting members. An excerpt from the rules of the competition showing the requirements for the connections can be found in Appendix G. The following design is for the penta-connections for the South Side 1 and 2 showing the difference in designs.

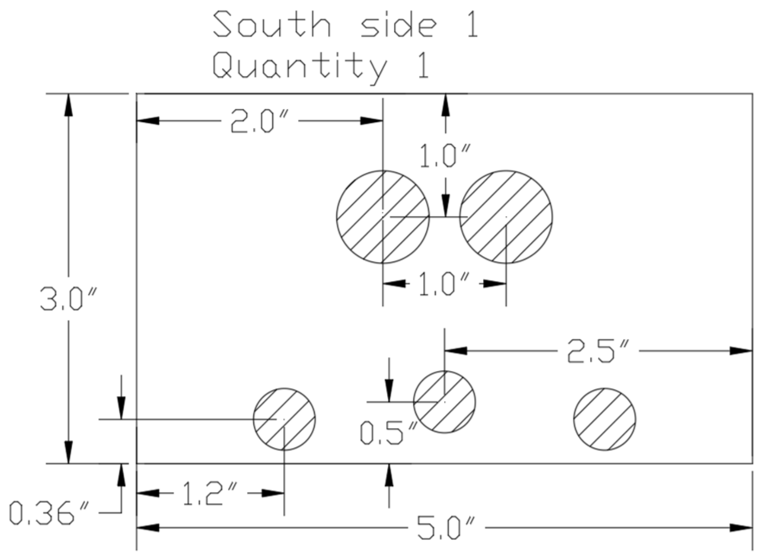

Figure 1 South Side 1 Connection Design

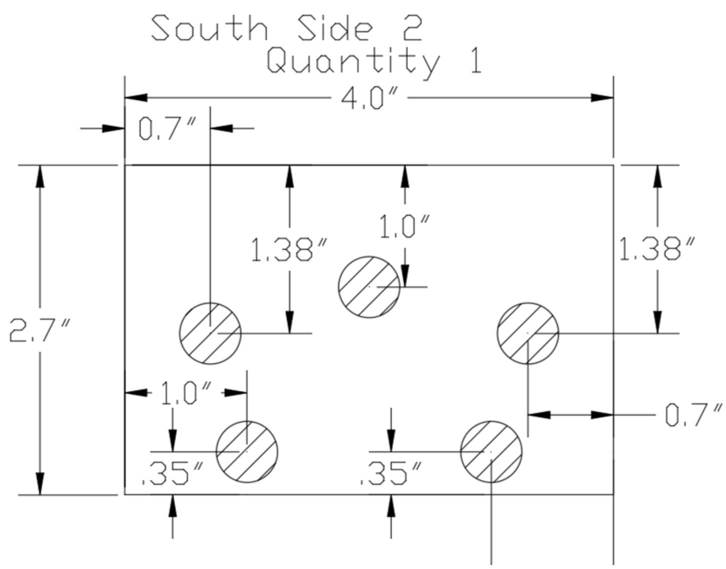

Figure 2 South Side 2 Connection Design

5.0 Final Design

5.1 Final RISA 3D Modeling

The final design RISA model can be found in Appendix J. The bridge spans approximately twenty-one feet which is the limit of the bridge competitions and specifications. The bridge spans in width approximately two feet six inches which is lower than the limit of three feet seven inches and higher than the limit of two feet as specified by the rules of the competition. The bridge features no members longer than three feet six inches as that is the limit for any given member. The bridge height meets the maximum height of twenty-eight inches as specified in the rules for the competition. Again, the final RISA 3D Model can be found below in Appendix J.

As mentioned in Section 3.1, RISA calculates the end reactions and deflections that the bridge will undergo when going through any of the load combinations and the self-weight. Through the calculations done by RISA, the highest load recorded on a single member is approximately two kips, meaning the connections must be able to withstand a minimum of two kips of force being applied. All the results are found in the 60 percent appendices and only the highest load scenario will be featured in this section.

	Member	Member End		Axial[lb]	LC	y Shear[lb]	LC	z Shear[lb]	LC	Torque[lb-ft]	LC	y-y Moment[lb-ft]	LC	z-z Moment[lb-ft]	LC
1	M20	I	max	1908.732	4	80.996	4	0	9	15.187	9	0	9	0	9
2			min	81.481	3	2.869	3	0	1	-1.448	3	0	1	0	1
3		J	max	1908.732	4	-2.869	7	0	9	15.187	9	0	9	0	9
4			min	81.481	3	-278.917	4	0	1	-1.448	3	0	1	0	1

Figure 4: Highest Loading Recording From RISA

5.2 Connections Calculations

As mentioned above, there are ninety-six total connections for the bridge for all the different connecting pieces. There are multiple tests to find different items for the connections such as the Bearing, Tear out Strength, Shear Strength, Design Tensile Strength, Nominal tensile strength, Tensile Rupture in the net area, Tensile yield in the gross area. The connection designs feature mostly rectangular designs with a single bolt going through each member at each connection. All the calculations for the different connections are found in Appendix H. These tests are completed for determining the strength of the connections and bolts. Specifically, to ensure that they can withstand the forces that will be put onto the bridge and break, rip, or tear through the steel and damage the entire project. All the following equations for all the following tests are from the AISC Specification for Structural Steel Buildings Chapter D, E, and J.

5.2.1 Equations and Results for Bolt Strength

Equation 1: Design Tensile Strength [4]

$$* F_{nt} * A_b = Design\ Tensile\ Strength\ of\ Bolts$$

Equation 2 Nominal Tensile Strength [4]

$$F_{nt} = \phi * F_u$$

Equation 3 Tear-Out Strength [4]

$$\phi * 1.5 * lc * t * Fu = Tear - Out\ Strength$$

Equation 4 Design Shear Strength [4]

$$\phi * F_{nv} * A_b = Design\ Shear\ Strength$$

Equation 5 Nominal Shear Strength of Bolts [4]

$$F_{nv} = .563F_u$$

These equations are used to find the strength the bolts can hold and withstand before tearing out and how much they can sustain. The abbreviations themselves for Equations 1 through 5 can be found above in List of Abbreviations, Table 1. The main two factors in these calculations are the yield strength and the tensile stress of the given bolt material the team selects. The team decided that the bridge will use Grade A325 bolts as they have an extremely high yield and tensile stress. The A325 bolts have a tensile stress of 105 KSI and the yield stress is ninety-two KSI. The bolts being used for this analysis are ½ ich screws and ¾ inch screws as they fit in the areas of the members of the bridge as the members are .78.7 in, one*one inch, and two*two inch in width and height.

The following table, Table 5, has the final values for the tests that need to be done for the bolts.

Table 5: Bolt Characteristics

Bolt A325	screw	screw
Bolt Characteristics	.5 inch	.75 inch
Bolt Fu Tensile stress (KSI)	105	105
Bolt Fy Yield stress (KSI)	92	92
Bolt Fnt Nominal Tensile strength (KSI)	78.75	78.75

Bolt Fnv Nominal shear strength (KSI)	44.33	44.33
Bolt area (in^2)	0.196	0.442
Bolt Design tensile strength (kips)	11.6	22.86
Bolt Tear-out stress (kips)	7.4	7.4
Bolt Bearing (kips)	11.1	16.6
Bolt Design Shear Strength (kips)	6.53	14.7

With these results, the bolts will be able to sustain approximately 7.4 kips before tearing out of the steel. This means that the most the bolts can take before tearing out of the connection and members are 7.4 kips. The biggest load that the bridge will be under is approximately two kips.

5.2.2 Buckling Test Equations for Connections

The buckling stress, as advised by our technical advisor Sabrina Ballard, was to be done only once for the connection with the highest loading. This is a hypothetical worst-case scenario, which is used to determine how much the steel can sustain before sliding and breaking. The connection that was chosen for the analysis is the top Penta-connection. This is because it gets the most force put on because it lays right where load combos are. Through RISA analysis as shown in Appendix D and Figure 4, the highest load on any member is approximately two kips in tension or compression. Using the dimensions chosen for the connection and the equations found in Section E3 in the AISC, the top penta-connection can sustain 20.5 kips of stress before buckling and failing.

Equation 6 Radius of Gyration [4]

$$r = (\frac{I}{A})^{.5}$$

Equation 7 Effective Length Lc [4]

$$Lc = K * L$$

Equation 8 Member Slenderness [4]

$$\frac{Lc}{r}$$

Equation 9 Elastic Buckling Stress [4]

$$F_e = \frac{\pi^2 * E}{(\frac{Lc}{r})^2}$$

Equation 10 Fcr Critical Stress [4]

$$Fcr = \left(.658^{\frac{Fy}{Fe}}\right) * Fy$$

Equation 11 Pn Nominal Compressive Strength Based on Limit State of Flexural Buckling [4]

$$Pn = \phi * Ag * Fcr$$

The abbreviations themselves for Equations 6 through 11 can be found above in List of Abbreviations, Table 2. The buckling stress in the top Penta-connection is determined to be 20.5 kips, the largest load that will be placed is approximately two kips. So, the amount of force the connection can sustain is over what the connection will sustain. This means that this connection is safe from buckling and in the worst-case scenario will not break.

Table 6: Results of Buckling for the Top-Penta Connections

Buckling stress numbers	
Moment of inertia in^4	11.25
Area of plate in^2	15
Radius of gyration in	0.866
K effective length factor	2
Lc effective length in	10
E ksi	29000 0
Lc/r member slenderness	11.547
Fe kips	2146.6
Fcr ksi	45.6
Area gross in^2	0.5

Buckling stress kip	**20.5**

5.2.3 Tensile Yield in Gross Section and Tensile Rupture in the Net Section Equations and Results

For the plates for the connections, they must be evaluated on two factors. The two factors are the yield strength in the cross-section and the rupture strength in the net area. The way these two tests are used is to ensure that the tensile yield strength is less than the rupture strength, that way the stress that will be applied will be in the range to make the connections break. The tensile strength of a material is how much a material can take before it cracks. The yield stress is how much the material can take without damaging or permanently deforming. The nominal tensile strength is the safety factor tensile strength using the safety factor of .75. The nominal shear strength is how much strength the material can take under the most extreme conditions and in the worst conditions. The tensile yield of the steel of the gross area and the tensile rupture of the net section is important for finding how much the strength of the steel can take before it ruptures and falls apart. This is to ensure that any modifications to the connections ensure that the yield stress is lower than the rupture stress and by dividing the yield by the rupture, the stress ratio can be established. The theoretical values are much larger than the actual worst scenario of two kips.

Equation 12 Gross Area [4]

$$Ag = thickness * height\ of\ connection\ plate$$

Equation 13 Net Area [4]

$$Ae = Ag - (((d + .125)^2) * thickness * (\frac{pi}{4}))$$

Equation 14 Tensile Yield in Gross Section [4]

$$.75 * Ag * Fy$$

Equation 15 Tensile Rupture in the Net Section [4]

$$.75 * Ae * Fu$$

The abbreviations themselves for Equations 12 through 15 can be found above in List of Abbreviations, Table 3. The results of this analysis, found below in Appendix H, show that the stress ratios, the tensile yield and rupture are within acceptable limits and do not exceed

100 percent for the theoretical tests using the design yield. For the actual load of two kips, the stress ratio is at most 50 percent meaning that the rupture strength is not going to be a problem for the connections that were designed. This means that the connections are in order as none of the calculations exceed 100 percent.

5.3 Shop Drawings

Shop drawings were made using the dimensions, labels, connections, bolts, and angles to ensure an understanding of construction and fabrication. In creating them, they were designed first on paper and then transmitted to AutoCAD. The connections are the only shop drawings since the team is going to cut the members themselves so the only drawings that are needed are for the welders and crafters for the connections. These can be seen below in Appendix I.

6.0 Fabrication

The fabrication of building our bridge will begin by cutting the square tubing to the desired size based on measurements determined in RISA. Once this is conducted, the team will cut their connections out of the four feet by twelve feet steel sheets provided by Page Steel. This process will be conducted by K Zell-Metals located in Phoenix, Arizona. The next step is to degrease and clean all the steel, so the team can take it down to get welded. Once all the desired parts are welded, the team can assemble the bridge with the desired bolts based on the drawings the team created. However, with all of this mentioned, the team ordered the steel and received the steel later than expected. Therefore, the team is behind and did not complete the fabrication of the bridge will not be completed by the sixty percent submittal.

6.1 Steel Cutting

The next part of the project will have the team prepare and cut the steel tubing to the desired dimensions based on the drawings the team has created. Initially, when cutting the steel, the first step will be to get a tape measure out all the dimensions based on the drawings in AutoCAD. As each measurement is measured throughout the steel, soapstone will be used to mark that specific measurement. A triangle tool will also be used to make sure the soapstone makes a straight line on all sides of the square tubing. After each measurement is decided throughout the steel, the team will use a hand grinder to cut the steel tubing. The way the team will use the hand grinder is to start by clamping down the steel tubing in the vice, as well as adjusting the grinder disk till the right one is determined. After this is conducted, the team will cut the steel over the measured measurements. This process was supposed to be conducted before the sixty percent submittal. However, due to ordering steel late, receiving steel late, and lack of supplies this process was not completed by the sixty percent submittal.

6.2 Preparing Steel

In preparing the steel for welding after cutting the steel, it will have to be cleaned. In cleaning the steel, two methods will be used. The first method is deburring the steel. Deburring the steel removes the sharp edges where all the cuts were made throughout the steel tubing. Furthermore, with smooth edges, the steel tubing will be completely uniform as well as create a tight fit when the steel tubing gets put into the connections. The tools that were used to complete this step were a table grinder and a hand grinder. The second method that was used to prepare the steel was a degreaser. The degreaser that was used on the steel was an acetone-based nail polish remover. The reason the steel must be degreased before welding is because greasy steel can cause weak welds which can increase the potential of breaking.

6.3 Welding

The welding done for the bridge construction will be done for some of the connections as well as all the glove connections for the ends. The bottom connection will have three sides with a base and two sides, which will feature additional plates that will require welding onto to ensure that it stays together. By enabling them to be welded together, it increases the strength of the connections and allows it to maintain a stronger tensile strength to hold all the members it connects. For the glove connections for the bottom members and normal diagonals, they will have an extra plate of 1/eighth thickness added to the welded plates to enclose the .25 in free space that the diagonals and bottom chords that are .7 inch by .7 inch will have with the one inch by 1-inch legs.

For the glove connections for the diagonal top chords, there are two connections for each one that is not at the end of the bridge. These require different angles that allow these connections to grasp the three members to ensure they do not slip or fall off. There are two connections for each lateral touching a leg member, one for the outside connecting parts and one for the inside touching members. These two connections will be welded with a single base plate with two additional plates welded at angles that the members are at. Two bolts will join the outside and inside connections for the diagonals with a single bolt on both sides with a bolt going through the two bases. These welded plates will have a lot of support and allow for them to properly connect the diagonal laterals and the legs to ensure that it stays in the proper place.

These are the only parts of the bridge that will be welded as all the other members and plates will only be cut and will not require any additional plating to close in the extra space that is left over. The bottom glove connections are the only ones that require this additional plating for the side welded members to ensure that the bridge will not slip, buckle, or tear out from the strain on the members.

7.0 Engineering Work

7.1 Comparison to Original Proposal

Regarding the original proposal of this project, the scope and schedule have been altered. The proposal schedule can be found in Appendix K. Task 8, Coordinated Assembly: Member Fabrication, and Task 9, Coordinated Assembly: Connection Fabrication both changed and took 14 days each, where both were finished on April 11th. Task 11, Team Assembly Construction Practice, only took 7 days instead of 26 days and was finished on April 14th. Task 12, Compete in Regional Competition, took 4 days instead of two days, which was finished on April 16th. The new modified schedule can be found in Appendix L.

The team lost about 19 days when it came to the Team Assembly Construction Practice because of the delay in starting our completed tasks as well as the under-estimating arrival of fabrication due to COVID Restrictions. However, the team did complete everything on time and was ready to compete in the AISC Student Steel Bridge Competition on April 16th, 2022.

7.2 SSBC Competition

Regarding the Student Steel Bridge Competition, was attended by the NAU ASCE Student Chapter for the Intermountain Southwest Conference. It lasted from April 13th until April 16th, 2022. The first full day of the conference was the Bridge Display Day. This lasted from 7 am until 12 pm. This was where the judges went around to look at each bridge to make sure they are in accordance with the aesthetic features of the bridge, as well as making sure that it qualifies to be used on the day of the competition. The judges also looked at and judged the Poster Presentation for each team. A big aspect of Display Day is to get to know other Steel Bridge teams from other schools to collaborate and ask questions about their bridges.

The second day of the conference was utilized as a practice day for the Steel Bridge teammates and the mentees. This is where we laid out all the members, connections, nuts, bolts, washers, tools, and PPE and did practice runs for the following day of the competition. Per the SSBC guidelines, only six people were allowed to construct on the day of the competition, which was decided when practicing.

The final day of the conference was our day of the competition. Per the SSBC guidelines, if construction time exceeded 45 minutes, judges would halt construction, [1] which is what happened in our case. Because the head judge approved, we were able to move our bridge off-site for continued, untimed construction. However, the bridge was not eligible for awards in any category. The bridge was later load tested when there was extra time but deflected and swayed four inches.

8.0 Engineering Costs

As seen below in Appendix M, the table shows the estimated breakdown of all the engineering services included in this project. This specifically includes the personnel and their individual pay rates, cost of materials, cost of equipment, the cost of a subcontractor who will be doing the labor, as well as the cost for travel with van rental, fuel, food, and lodging. The estimated cost for the Steel Bridge Project is approximately $145,899.

8.1 Personnel Costs

The summarized billing rates for the personnel working are presented below in Appendix M. The total staff rate breakdown is seen, with their corresponding roles being the Senior Engineer, Project Engineer, the Engineers in Training, the Interns, the Drafter, and Administration. They worked for a total of 870 hours. Their rates per hour can be seen in Appendix M, coming to a total of $66,935.

8.2 Material Costs

Pertaining to the materials and equipment, the table is seen in Appendix M. Materials include the steel members, connections, and hardware. The members, connections, nuts, bolts, washer, and locks were all donated, the only thing that was paid for in that category was the shipment of our steel to get to Flagstaff, AZ. The equipment includes the tools required for construction and assembly, as well as the mileage and gas to and from Phoenix, AZ to pick up things needed for our bridge. For tools, we bought impact drills sets, personal protective equipment, tool belts, wrenches, grinder blades, duct tape, degreaser spray, etc. The total in this category was $1039.37.

The subcontract included KZell-Metals, Page Steel, Copper State, and Mario Hernandez. All the services they provided were donated, therefore we did not get charged anything. The travel expenses on the trip are accurate according to the NAU ASCE protocols that were followed. However, it was a discounted club rate of $160 for regular ASCE Members and $80 for ASCE Officers and Team Captains. The team paid a total of $480 for the trip to UNLV.

9.0 Impact Analysis

This capstone project corresponds to various impacts. Specifically, the competition itself and the hypothetical scenario given for the competition of the bridge. The impacts include the social, environmental, and economic impacts.

9.1 Social Impacts

For the competition's social impacts, a positive impact is the competition promotes interactions between students and industry professionals to show what awaits students when they finish their education. Thus, creating bonds and connections that may help students in the future when looking for careers. Another positive impact is that the competition encourages speaking with other teams to get new ideas and insights on how to go about the bridge designing.

For the actual bridge's social impacts, a positive impact is that the bridge is used as transportation for animals to get where they need to go once the bridge is built. Thus, animals won't have the risk of running into traffic and getting hit. Another impact is that the bridge will connect colleagues working on the project, allowing for connections to be made and help people make advancements through their careers.

9.2 Environmental Impacts

For the competition's environmental impacts, a positive impact is that the remaining usable material was transported back to the NAU field station for other teams in the future to use if needed. Thus, minimizing a need for steel from other companies that may sponsor the team's and school's future projects. A negative environmental impact is that it increases production for steel use as more steel will always be required and it leads to smelting and environmental damages.

For the bridge's environmental impacts, a positive impact is that it will save animals from being hit from drivers. A negative environmental impact is that the bridge will consume a large amount of fuel, steel, and other resources. Another negative impact is that there is no way for the animals to travel safely while the bridge is under construction.

9.3 Economic Impacts

For the competition's economic impacts, an impact is that it increases demand for steel goods as more teams and schools will want to continue participating. This leads to businesses being able to manufacture more steel for schools to use. Companies gain advertising through the competition and the schools and teams will be able to save money if the steel was donated.

For the bridge's economic impacts, a positive impact is that the bridge will supply jobs for people who work on the project, thus helping drive the economy. A negative impact, however, is that the bridge will decrease the use of the highway to ensure that the bridge will not risk any accidents to occur until construction is completed. Another economic impact is that the bridge material is expensive and will be very costly to build.

11.0 Conclusion

This project entailed using various design and analysis methods to design and construct a functional bridge that can support a defined amount of loading and meet the specifications defined by the competition rules and requirements. Per the hypothetical problem statement, the bridge had to be designed to support the weight of the green surface, wildlife, pedestrians, and maintenance and park vehicles.

The final design for the bridge was completed using RISA 3D and the connections were designed and analyzed to exceed the demand using AutoCAD. The competition aspect of the project was completed and finalized, with scoring in 8th place out of 9 other schools.

11.1 Failure Analysis

The failure of the bridge stems from multiple factors regarding its construction and way the team went about it, with the main problem being that the team started late on the project. Regarding the connections, there were a lot of plate connections with none of them welded. Thus, the team was unable to meet the building time requirements. In the construction process of the bridge, there were edits made to the Penta connections for the top and bottom chords to change bolt holes on the members. Another consequence of not having welded connections is that it led to an increase of swaying and increased deflection. The new connection shop drawings for the north and south side are in appendix I: Shop Drawings. Another reason for failure is the small footings in the design of the bridge. The team did not follow the competition guidelines as to where the footings had to be placed, thus not having enough room to be able to stand up in the construction zone. This caused an increase in construction time and less stability of the bridge to stand up on its own.

Another reason for the bridge failing is the lack of the diagonal laterals that were to be included in the design. This would have helped with the sway and deflection of the bridge, as well as the overall stability of the bridge. Again, due to timing issues and changes made during construction, they couldn't be included and led to the failure of the bridge. Overall, the biggest reason for the failure of the bridge, as mentioned before, is the team starting late on the construction process of the bridge. If the team were to have started earlier and considered how long the construction process is, that would have changed the overall outcome of the bridge and its placement at competition.

11.1 Engineering Response

The engineering response that the team has as to why the bridge failed is the lack of the diagonal laterals. Those would have helped the bridge with its overall stability and construction. The footings not being large enough and being too small led to the bridge not being able to stand on its own, or not sway with any load or force being put upon it. The bridge itself had various connections that were not welded on, thus being too loose. This also led to swaying and increased deflection in the bridge, leading to failure. For future teams, we advise to not procrastinate designing and formatting the connections and designs, especially not to take any shortcuts in this process. We also advise to always label every connection that may need to be different. This is to ensure that the connections ordered are correct, corresponding to its dimensions specifically. We did not follow this, which lead to an increase in time to redesign and a decrease in time for construction of the bridge.

12.0 References

References

[1] AISC, "SSBC 2022 Rules," [Online]. [Accessed 05 February 2022].

[2] machines4u, "4 Types of Truss Bridges: Which is Worth the Weight?," [Online]. Available: https://www.machines4u.com.au/mag/4-types-of-truss-bridges-which-is-worth-the-weight/#:~:text=The%20four%20most%20basic%20categories,Pratt%2C%20Howe%20and%20K%20Truss.. [Accessed 2022 February 2022].

[3] Boyer Steel Inc, "A500 Grade B ASTM Specifications," [Online]. Available: https://www.boyersteel.com/resource-astm-specifications/a500-grade-b/. [Accessed 08 February 2022].

[4] AISC, "Specification for Structural Steel Buildings," [Online]. Available: https://www.aisc.org/globalassets/aisc/publications/standards/a360-16-spec-and-commentary.pdf. [Accessed 08 February 2022].

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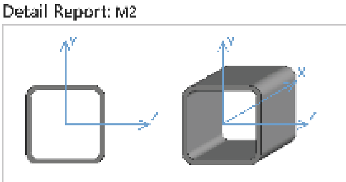
13.0 Appendices

13.1 Appendix A- RISA Solved Engineering Values

Company : Steel Bridge Team		4/19/2022
Designer : mth272		6:24:11 PM
Job Number : 1		Checked By : ________
Model Name : Steel Bridge		

Detail Report: M2 | Unity Check: 0.018 (LC 2) | Load Combination: Envelope



Input Data:

Shape:	1 walll .065	I Node:	N27
Member Type:	Column	J Node:	N28
Length (in):	18.15	I Release:	Fixed
Material Type:	Hot Rolled Steel	J Release:	Fixed
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	67	J Offset (in):	N/A

Material Properties:

Material:	A500 Gr.B RECT	Therm. Coeff. (1e⁵°F⁻¹):	0.65	R_y:	1.4
E (ksi):	29000	Density (k/ft³):	0.527	F_u (psi):	58000
G (ksi):	11154	F_y (psi):	46000	R_t:	1.3
Nu:	0.3				

Shape Properties:

d (in):	1	I_{yy} (in^4):	0.036	Area (in^2):	0.243
b_f (in):	1	I_{zz} (in^4):	0.036	J (in^4):	0.055
t (in):	0.065				

Design Properties:

$L_{b\,y\text{-}y}$ (in):	18.15	$K_{y\text{-}y}$:	1	Max Defl Ratio:	L/2000
$L_{b\,z\text{-}z}$ (in):	18.15	$K_{z\text{-}z}$:	1	Max Defl Location:	0
$L_{comp\,top}$ (in):	18.15	y sway:	No	Span:	N/A
$L_{comp\,bot}$ (in):	18.15	z sway:	No		
L_{torque} (in):	18.15	Function:	Lateral		
		Seismic DR:	None		

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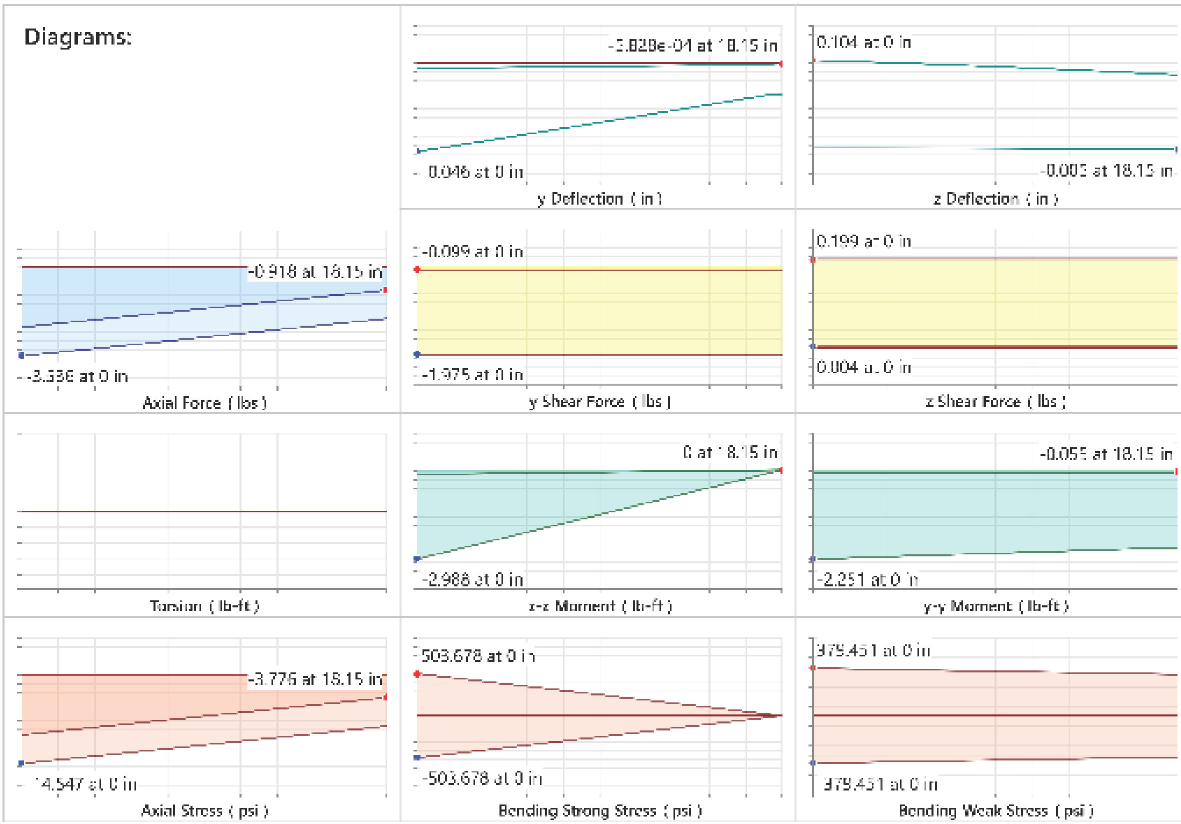
Company : Steel Bridge Team
Designer : mth272
Job Number : 1
Model Name : Steel Bridge

4/19/2022
6:24:11 PM
Checked By : ________



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AISC 15th (360-16): LRFD Code Check

Limit State	Gov. LC	Required	Available	Unity Check	Result
Applied Loading - Bending/Axial	2				-
Applied Loading - Shear + Torsion	2	-	-	-	-
Axial Tension Analysis	2	3.51 lb	10064.34 lb	-	-
Axial Compression Analysis	2	0.000 lb	8650.737 lb		-
Flexural Analysis (Strong Axis)	2	2.988 lb-ft	294.54 lb-ft	-	-
Flexural Analysis (Weak Axis)		2.251 lb-ft	294.54 lb-ft	-	-
Shear Analysis (Major Axis y)	2	1.975 lb	2599.506 lb	0.000	Pass
Shear Analysis (Minor Axis z)	2	0.193 lb	2599.506 lb	0.000	Pass
Bending & Axial Interaction Check (UC Bending Max)	2	-	-	0.016	Pass
Torsional Analysis	2	0.000 lb-ft	233.058 lb-ft	0.000	Pass

`

13.2 Appendix B- SSBC Rules and Guidelines, Section 9.3 [1]

9.3 USABILITY

Specifications in this Sub-Section (9.3) are illustrated by the Bridge Elevation Diagram.

A weight penalty will be assessed for each specification in this Sub-Section (9.3) that is violated, rather than for every violation of that specification. If there are multiple violations of the same specification, the penalty will be based on the largest violation.

The penalty for violation of each of the specifications in this Sub-Section (9.3) will be an addition to the weight of the *bridge* determined as follows:

(1) 20 pounds for a dimensional violation not exceeding 1/4",
(2) 100 pounds for a violation greater than 1/4" but not exceeding 1",
(3) 200 pounds for a violation greater than 1" but not exceeding 2"
(4) 400 pounds for a violation greater than 2" but not exceeding 3", and
(5) if a violation exceeds 3", the *bridge* will not be eligible for awards in any category, except *aesthetics* and *video*. The *bridge* may be *load* tested at the *head judge's* discretion if that can be done safely within available time.

9.3.1 The *bridge* shall not touch the *highway* or the *ground* outside the *footings* except when the exception in Sub-Section 10.4.2 is invoked

9.3.2 The *bridge* shall not be wider than 3'-7" at any location along the span.

9.3.3 Vertical clearance shall be provided at all points directly over the *ground* and *highway*. The clearance shall be no less than 7.5", measured from the surface of the *ground* or *highway*. Parts of the *bridge*, including *nuts* and *bolts*, shall not extend below this limit. Exception 1: No clearance is required for the portion of the *bridge* for which the exception in Sub-Section 10.4.2 is invoked. Exception 2: No clearance is required over the *footings* except as necessary to accommodate restraint applied during the lateral *load* tests described in Sub-Section 11.4.1.

9.3.4 The *bridge* shall provide a straight, clear passageway conforming to the Backspan Clearance *Template* detail and Cantilever Clearance *Template* detail on the Bridge Elevation Diagram.

9.3.4.1 A 2' wide by 1'-10" high passageway conforming to the Backspan Clearance *Template* detail on the Bridge Elevation Diagram shall extend underneath the *bridge* from the beginning of the bridge on the west end to the west edge of the *south side*, *east end footing* as shown on the Bridge Elevation Diagram.

9.3.4.2 A 2' wide by 1'-4" high passageway conforming to the Cantilever Clearance *Template* detail on the Bridge Elevation Diagram shall extend underneath the *bridge* from the west edge of the *south side*, *east end footing* to the end of the *bridge* on the *east end* as shown on the Bridge Elevation Diagram.

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9.3.5 At the ends of the *bridge*, parts of the *bridge* shall not extend away from the *highway* beyond the vertical planes that make up the *construction zone* boundary shown on the Bridge Plan Diagram.

9.3.6 Each *stringer* shall be at minimum 20 feet long and at maximum 21 feet long, measured along their top.

9.3.7 The tops of the *stringers* shall be the highest point on the bridge and extend no more than 2'-4" and no less than 1'-11" above the surface of the *highway*, *ground*, or *footings* at any location along the span.

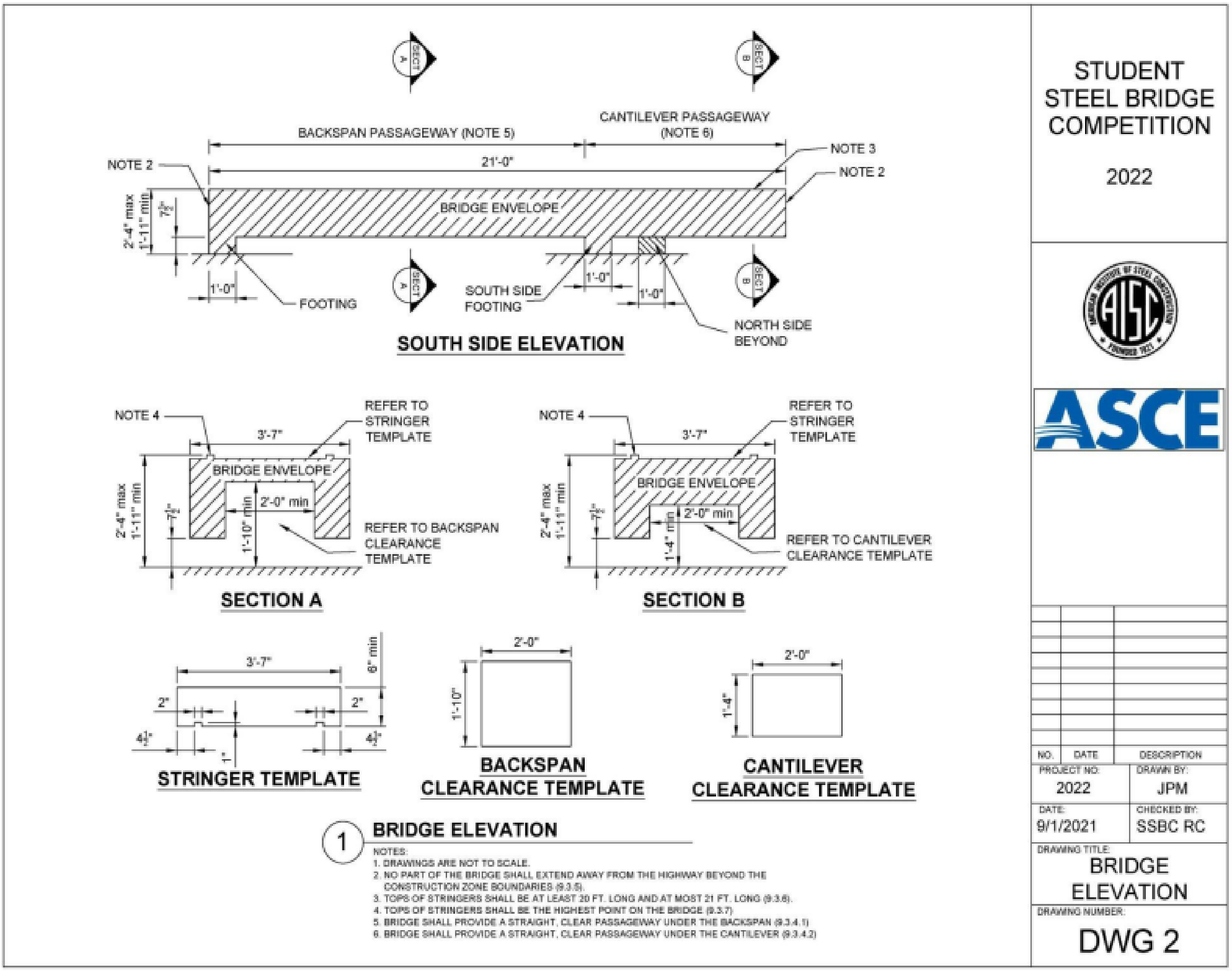
9.3.8 The *bridge* shall provide a straight, clear decking support location conforming to the Stringer *Template* detail on the Bridge Elevation Diagram. To verify compliance with 9.3.8.1 and 9.3.8.2, *judges* will slide the stringer *template* along the tops of the *stringers* while holding it plumb and perpendicular to the span of the *bridge*. If the same obstruction causes a violation of both 9.3.8.1 and 9.3.8.2, the *judge* will record only the larger violation.

9.3.8.1 At no location along the full length of the *stringers* shall part of the *bridge*, including *nuts* and *bolts*, obstruct passage of the stringer *template*. The measurement for non-compliance with 9.3.8.1 is the distance an obstruction projects onto the stringer *template*, measured perpendicularly from the obstructed edge.

9.3.8.2 The tops of both *stringers* shall contact the tops of the two rabbets in the stringer *template* at every location along the full length of the *stringers* during the verification procedure described in 9.3.8. The measurement for non-compliance with 9.3.8.2 is the vertical distance between the top of a rabbet and the top of the corresponding *stringer*.

9.3.9 Tops of *stringers* shall be free of holes, splits, separations, protrusions, and abrupt changes in elevation or slope, except that between adjacent *members* that comprise a *stringer* there may be a horizontal separation not exceeding 1/4" and a change in elevation not exceeding 1/8".

13.3 Appendix C- SSBC Cantilever Example with Dimensions [1]



13.4 Appendix D- RISA End Reactions Solved Engineering Values

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RISA	Company : Steel Bridge Team Designer : mth272 Job Number : 1 Model Name : Steel Bridge	4/19/2022 3:26:35 PM Checked By : __________

Member End Reactions (By Combination)

	LC	Member Label	Member End	Axial[lb]	y Shear[lb]	z Shear[lb]	Torque[lb-ft]	y-y Moment[lb-ft]	z-z Moment[lb-ft]
1	8	M2	I	-2.912	-1.127	6.612	0	-8.88	-1.705
2			J	-1.432	-1.127	6.612	0	1.12	0
3	8	M4	I	140.936	-1.064	0.651	-0.268	-0.453	-1.153
4			J	145.925	-0.526	0.498	-0.268	-0.061	0
5	8	M5	I	521.33	1.046	0	0.178	0	0
6			J	520.245	-1.046	0	0.178	0	0
7	8	M6	I	1.759	0.19	-0.381	0	0.87	0.288
8			J	3.239	0.19	-0.381	0	0.294	0
9	8	M8	I	84.197	11.835	0.132	0.212	0.784	1.797
10			J	89.201	-1.081	0.076	0.212	0.675	0
11	8	M9	I	-1055.141	1.046	0	-0.363	0	0
12			J	-1056.226	-1.046	0	-0.363	0	0
13	8	M10	I	-3.484	2.811	-0.134	0	0.649	4.251
14			J	-2.004	2.811	-0.134	0	0.446	0
15	8	M13	I	596.441	0.627	0	-1.006	0	0
16			J	595.357	-0.627	0	-1.006	0	0
17	8	M14	I	-2.748	1.667	-0.176	0	-0.721	2.521
18			J	-1.267	1.667	-0.176	0	-0.987	0
19	8	M16	I	143.809	2.863	-0.468	-0.34	-1.164	3.989
20			J	145.289	2.863	-0.468	-0.34	-1.872	-0.342
21	8	M17	I	19.068	6.148	0.049	-0.17	-1.153	-0.401
22			J	429.771	-14.828	-0.472	0	0	0
23	8	M19	I	6.35	2.954	0	14.776	0	0
24			J	6.35	-2.954	0	14.776	0	0
25	8	M20	I	1517.549	2.869	0	10.575	0	0
26			J	1517.549	-2.869	0	10.575	0	0
27	8	M21	I	1516.907	137.877	0	7.429	0	0
28			J	1516.907	-340.263	0	7.429	0	0
29	8	M22	I	1221.618	294.389	0	-2.046	0	0
30			J	1221.618	-89.305	0	-2.046	0	0
31	8	M23	I	1233.121	2.954	0	-12.599	0	0
32			J	1233.121	-2.954	0	-12.599	0	0
33	8	M24	I	-625.871	2.954	0	-32.464	0	0
34			J	-625.871	-2.954	0	-32.464	0	0
35	8	M25	I	-624.713	61.299	0	-34.837	0	0
36			J	-624.713	-108.92	0	-34.837	0	0
37	8	M26	I	-2.948	118.445	0	-25.521	0	0
38			J	-2.948	-118.445	0	-25.521	0	0
39	8	M27	I	-803.934	1.046	0	1.06	0	0
40			J	-803.934	-1.046	0	1.06	0	0
41	8	M28	I	-802.802	1.016	0	-0.06	0	0
42			J	-802.802	-1.016	0	-0.06	0	0
43	8	M29	I	-1993.333	1.046	0	0.191	0	0
44			J	-1993.333	-1.046	0	0.191	0	0
45	8	M30	I	-1993.523	1.046	0	-0.103	0	0
46			J	-1993.523	-1.046	0	-0.103	0	0
47	8	M31	I	-298.111	1.046	0	-0.542	0	0
48			J	-298.111	-1.046	0	-0.542	0	0
49	8	M32	I	-300.925	1.046	0	-0.988	0	0
50			J	-300.925	-1.046	0	-0.988	0	0
51	8	M33	I	173.959	0.627	0	-1.958	0	0
52			J	173.959	-0.627	0	-1.958	0	0
53	8	M34	I	172.289	0.627	0	-0.97	0	0
54			J	172.289	-0.627	0	-0.97	0	0
55	8	M36	I	-5.072	1.235	3.715	0	-5.641	1.643
56			J	-1.839	0.842	4.014	0	0.677	0
57	8	M38	I	138.483	0.822	0.277	-0.302	-0.364	1.243
58			J	139.963	0.822	0.277	-0.302	0.055	0

Member End Reactions (By Combination) (Continued)

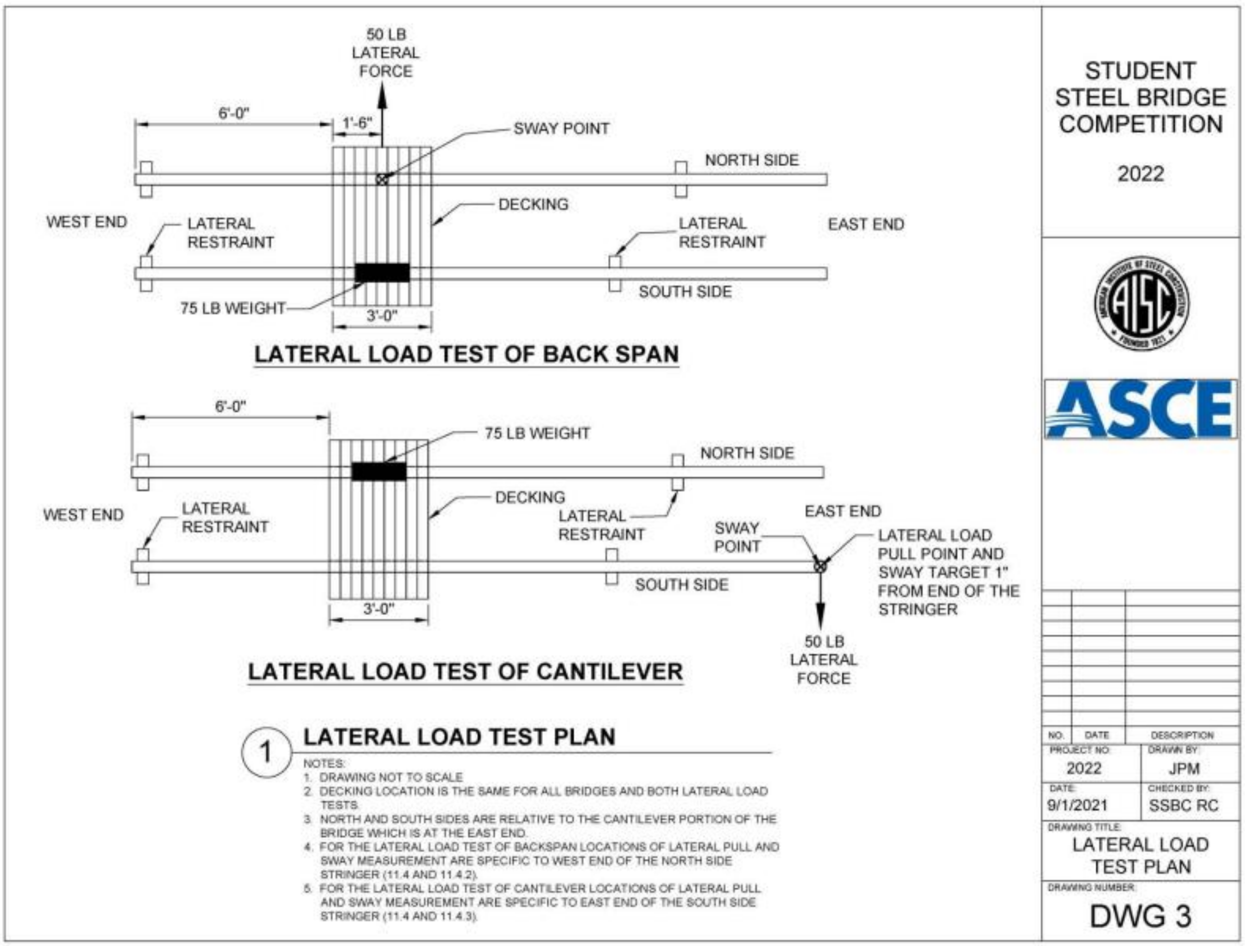
	LC	Member Label	Member End	Axial[lb]	y Shear[lb]	z Shear[lb]	Torque[lb-ft]	y-y Moment[lb-ft]	z-z Moment[lb-ft]
59	8	M39	I	211.368	1.04	0	0.23	0	0
60			J	210.284	-1.04	0	0.23	0	0
61	8	M40	I	-5.048	-5.185	4.587	0	-0.996	0.198
62			J	-0.021	1.237	-0.314	0	0.378	0
63	8	M42	I	111.796	-0.721	0.579	0.264	-0.29	-1.091
64			J	113.276	-0.721	0.579	0.264	0.586	0
65	8	M43	I	-1461.948	1.04	0	-0.512	0	0
66			J	-1463.033	-1.04	0	-0.512	0	0
67	8	M45	I	24.095	-2.607	-2.283	0.331	1.967	-5.09
68			J	25.575	-2.607	-2.283	0.331	-1.485	-1.147
69	8	M47	I	-4.292	-2.743	-0.282	0	0.202	-3.223
70			J	-1.567	-2.631	-0.104	0	-0.494	0
71	8	M49	I	124.972	-2.582	-0.432	-0.275	-1.057	-3.989
72			J	126.452	-2.582	-0.432	-0.275	-1.71	-0.083
73	8	M50	I	-9.502	-5.517	-0.046	-0.176	-0.792	0.401
74			J	247.694	13.368	-0.522	0	0	0
75	8	M51	I	1102.478	-5.462	-1.09	0	-3.227	-0.591
76			J	1106.87	0.159	2.637	0	0	0
77	8	M52	I	-5.686	2.937	0	14.239	0	0
78			J	-5.686	-2.937	0	14.239	0	0
79	8	M53	I	930.417	2.852	0	11.956	0	0
80			J	930.417	-2.852	0	11.956	0	0
81	8	M54	I	931.051	130.616	0	8.418	0	0
82			J	931.051	-333.324	0	8.418	0	0
83	8	M55	I	42.262	301.407	0	-2.758	0	0
84			J	42.262	-96.42	0	-2.758	0	0
85	8	M56	I	41.697	2.937	0	-14.653	0	0
86			J	41.697	-2.937	0	-14.653	0	0
87	8	M57	I	-695.921	2.194	0	-38.816	0	0
88			J	-695.921	-2.194	0	-38.816	0	0
89	8	M58	I	-698.87	23.563	0	-32.074	0	0
90			J	-698.87	-91.942	0	-32.074	0	0
91	8	M59	I	2.78	146.646	0	-23.213	0	0
92			J	2.78	-146.646	0	-23.213	0	0
93	8	M60	I	-466.273	1.04	0	0.865	0	0
94			J	-466.273	-1.04	0	0.865	0	0
95	8	M61	I	-467.114	1.01	0	0.188	0	0
96			J	-467.114	-1.01	0	0.188	0	0
97	8	M62	I	-1104.363	1.04	0	0.292	0	0
98			J	-1104.363	-1.04	0	0.292	0	0
99	8	M63	I	-1105.601	1.04	0	-0.086	0	0
100			J	-1105.601	-1.04	0	-0.086	0	0
101	8	M64	I	1261.722	1.04	0	-0.269	0	0
102			J	1261.722	-1.04	0	-0.269	0	0
103	8	M65	I	1260.526	0.777	0	-2.25	0	0
104			J	1260.526	-0.777	0	-2.25	0	0
105	8	M66	I	177.198	0.777	0	-1.313	0	0
106			J	177.198	-0.777	0	-1.313	0	0
107	8	M67	I	179.831	0.777	0	-0.819	0	0
108			J	179.831	-0.777	0	-0.819	0	0
109	8	M68	I	0.082	16.132	0.16	-0.401	-0.17	15.929
110			J	0.082	12.447	0.16	-0.401	0.176	-15.031
111	8	M69	I	0.181	5.572	-0.335	-1.669	0.356	4.712
112			J	0.181	1.888	-0.335	-1.669	-0.371	-3.37
113	8	M70	I	0.178	-0.866	0.263	-1.194	-0.268	-2.675
114			J	0.178	-4.55	0.263	-1.194	0.302	3.193
115	8	M71	I	-2.436	-7.862	-0.054	0.043	0.037	-10.594
116			J	-2.436	-11.547	-0.054	0.043	-0.08	10.437

Member End Reactions (By Combination) (Continued)

	LC	Member Label	Member End	Axial[lb]	y Shear[lb]	z Shear[lb]	Torque[lb-ft]	y-y Moment[lb-ft]	z-z Moment[lb-ft]
117	8	M72	I	-0.227	-8.745	-0.22	1.448	0.212	-11.386
118			J	-0.227	-12.431	-0.22	1.448	-0.264	11.566
119	8	M73	I	1.322	-18.086	0.061	3.447	-0.505	-20.989
120			J	1.322	-21.773	0.061	3.447	-0.371	22.222
121	8	M74	I	2.462	5.71	-0.571	3.037	0.995	2.39
122			J	2.462	1.763	-0.571	3.037	-0.331	-6.284
123	8	M75	I	-0.233	11.208	0.182	4.232	-0.86	9.74
124			J	-0.233	7.456	0.182	4.232	-0.459	-10.849
125	8	M76	I	-0.002	25.36	0.284	3.989	-0.34	26.686
126			J	-0.002	21.676	0.284	3.989	0.275	-24.27
127	8	M77	I	-826.889	1.016	0	0.395	0	0
128			J	-825.804	-1.016	0	0.395	0	0
129	8	M78	I	852.677	1.046	0	-0.098	0	0
130			J	853.762	-1.046	0	-0.098	0	0
131	8	M79	I	1041.023	1.046	0	-0.733	0	0
132			J	1042.108	-1.046	0	-0.733	0	0
133	8	M80	I	-510.86	1.01	0	0.412	0	0
134			J	-509.776	-1.01	0	0.412	0	0
135	8	M81	I	1206.287	1.04	0	-0.058	0	0
136			J	1207.371	-1.04	0	-0.058	0	0
137	8	M82	I	881.858	1.046	0	0.369	0	0
138			J	882.942	-1.046	0	0.369	0	0
139	8	M83	I	546.252	1.04	0	0.381	0	0
140			J	547.337	-1.04	0	0.381	0	0
141	8	M84	I	-688.873	1.552	0.279	-1.174	-1.561	1.999
142			J	-687.789	-0.002	0.279	-1.174	-0.825	-0.049
143	8	M85	I	637.67	1.668	0.517	-0.919	0.233	1.098
144			J	636.585	0.115	0.517	-0.919	1.599	-1.257
145	8	M86	I	-223.496	1.461	-0.277	-0.573	-0.003	1.725
146			J	-222.412	-0.092	-0.277	-0.573	-0.735	-0.083
147	8	M87	I	-224.691	0.864	-0.309	-0.46	-0.131	0.204
148			J	-223.606	-0.391	-0.309	-0.46	-0.847	-0.342
149	8	M88	I	70.623	0.901	2.526	0.995	-5.694	1.976
150			J	948.136	1.664	2.136	0	0	0
151	8	M91	I	-0.489	1.752	0	0.42	0	0
152			J	-0.489	0	0	0.42	0	-1.568
153	8	M92	I	-0.489	0	0	0.42	0	-1.568
154			J	-0.489	-1.752	0	0.42	0	0
155	8	M93	I	0.204	1.758	0	-0.09	0	0
156			J	0.204	0	0	-0.09	0	-1.58
157	8	M94	I	0.204	0	0	-0.09	0	-1.58
158			J	0.204	-1.758	0	-0.09	0	0
159	8	M95	I	-7.974	1.744	0	0.135	0	0
160			J	-7.974	-0.002	0	0.135	0	-1.553
161	8	M96	I	-7.974	0.002	0	0.135	0	-1.553
162			J	-7.974	-1.744	0	0.135	0	0
163	8	M97	I	8.145	1.799	0	0.43	0	0
164			J	8.145	0.002	0	0.43	0	-1.654
165	8	M98	I	8.145	-0.002	0	0.43	0	-1.654
166			J	8.145	-1.799	0	0.43	0	0
167	8	M99	I	0.321	1.811	0	-1.272	0	0
168			J	0.321	0	0	-1.272	0	-1.675
169	8	M100	I	0.321	0	0	-1.272	0	-1.675
170			J	0.321	-1.811	0	-1.272	0	0
171	8	M101	I	-0.214	1.245	0	0.927	0	0
172			J	-0.214	-1.245	0	0.927	0	0

`

13.5 Appendix E- SSBC Lateral Loading Example [1]



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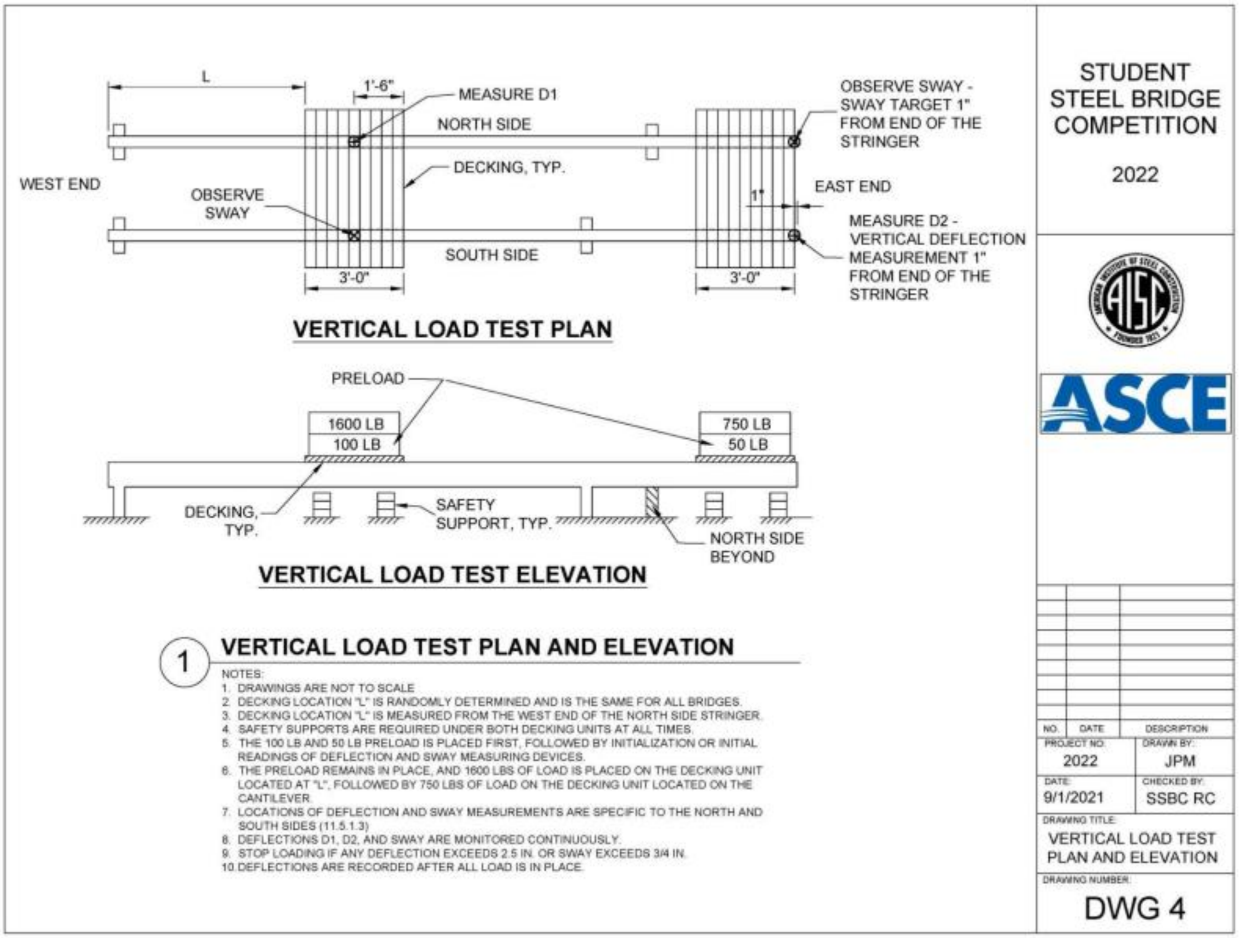
13.6 Appendix F- SSBC Vertical Loading Example [1]



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13.7 Appendix G- SSBC Rules and Guidelines, Section 9.4 [1]

9.4.1 All locations where one *member* touches another *member* require a connection. Multiple members may be connected at the same location. **Penalty is two minutes added to *construction time* for each individual violation regardless of whether the violation is corrected. If two members are touching, no connection exists between these two members anywhere, and the violation cannot be corrected, then the *bridge* will not be eligible for awards in any category, except *aesthetics* and *video*, and will not be *load* tested.**

9.4.2 A connection shall contain at least one and at most two *faying surfaces* associated with each *member* being connected with every *faying surface* penetrated by at least one *loose bolt* secured by a *loose* or welded *nut* such that the *member(s)* cannot be separated without first unscrewing and removing the *loose bolt(s)* that connects them. Cam locks, dovetails, tube-in-tube/sleeved and other mechanical/interlocking connections that are designed to resist movement without the presence of a *bolt* are prohibited. *Faying surfaces* are the only locations where *members* are in contact with each other. A *loose bolt* may connect more than two *members*. **Penalty is five minutes added to *construction time* for each individual violation.**

9.4.3 Each individual hole in a *member* for a *loose bolt* shall be completely surrounded by the *member*. Furthermore, such holes in the outer plies of a connection shall be small enough that the *nut* or *bolt* head cannot pass through. **Penalty is five minutes added to *construction time* for each individual violation.**

13.8 Appendix H- Calculations Completed

*Overlap onto next page

Number of connections	Connection	Gross Area (in^2)	Ag (in^2)	Net Area (in^2)	Phi for safety	Tensile yield in the gross section (Kip)	Tensile Rupture in the Net Section (Kip)	Theoretical Stress Ratio design/capacity	actual worst-case scenario 2 kip	Block Shear strength	Notes
24	diagonal laterals	0.125	0.125	0.1	0.75	4.31	4.35	0.991	0.459	Not needed	
8	top vertical Penta	0.375	0.375	0.35	0.75	12.9	15.2	0.85	0.131	Not needed	
14	top tri horizontal	0.5	0.5	0.425	0.75	17.3	18.5	0.933	0.108	Not needed	
4	top back vertical	0.5	0.5	0.425	0.75	17.25	18.4875	0.93306288	0.108181204	Not needed	
4	top end horizontal	0.25	0.25	0.211	0.75	8.625	9.1785	0.939696029	0.217900528	Not needed	
4	top end side vertical	0.5	0.5	0.425	0.75	17.25	18.4875	0.93306288	0.108181204	Not needed	

`

4	bottom end glove	0.25	0.25	0.211	0.75	8.625	9.1785	0.939696029	0.217900528	Not needed	needs .5 inches from the bottom
8	bottom tri glove	0.5	0.5	0.425	0.75	17.25	18.4875	0.93306288	0.108181204	Not needed	needs .5 inches from the bottom
6	bottom Penta gloves	0.3375	0.3375	0.3	0.75	11.64375	13.05	0.892241379	0.153256705	Not needed	needs .5 inches from the bottom
4	bottom cantilever	0.5875	0.5875	0.5	0.75	20.26875	21.75	0.931896552	0.091954023	Not needed	needs .5 inches from the bottom
2	end diagonals	0.25	0.25	0.212	0.75	8.625	9.222	0.9352635	0.216872696	Not needed	needs .5-inch diameter screws
7	outer diagonals	0.125	0.125	0.173	0.75	4.3125	7.5255	0.573051625	0.265763072	Not needed	needs .5-inch diameter screws
7	inner diagonal	0.125	0.125	0.173	0.75	4.3125	7.5255	0.573051625	0.265763072	Not needed	needs .5-inch

`

											diameter screws
96											

Top Penta Connection	
Worst case buckling	
l	5
h	3
I (in^4)	11.25
A (in^2)	15
r (in)	0.866
Lc (in)	10
Length (in)	5
K	2
Lcr/r	11.5
E (KSI)	29000
Lc/r<>4.71*sqrt(E/Fy)	<
4.71*sqrt(E/Fy)	118.2
Fe (k)	2146.7

`

Fcr (KSI)	45.58926831

Buckling stress	.9Pn=Fcr*Ag		Ag=t*h		
Fcr*Ag	22.79463415	K	t=	0.125	in
.9*Pn	20.51517074	K	h	4	in
			Ag	0.5	in^2

Shaped A500 B				
yield stress Fy	46000	psi	46	KSI
Tensile stress Fu	58000	psi	58	KSI
Fnt= nominal tensile strength	43.5	KSI		
	.5 in		**.75 inch**	
Design Tensile Strength J3-1 Bolts				
.75*Fnt*Ab	11.5968948	kip	22.8624497	kip
Fnt= nominal tensile strength bolts	78.75	KSI	69	KSI

`

Ab= nominal unthreaded area of bolt in^2	0.19634954	in^2	0.44178647	in^2
Bearing J3-6b	**.5 in screws**		**.75 in screws**	
.75*3*d*t*Fu	11.07	K	16.6	k
d=nominal fastener diameter in	0.5	in	0.75	in
t= thickness of connected material	0.125	in	0.125	in
Tearout J3-6d				
.75*1.5*lc*t*Fu	7.3828125	kips	7.3828125	kips
Lc=Clear distance, in direction of force, between the edge of the hole and the edge of the material	0.5	in	0.5	in

`

Design Shear Strength J3-1 bolts	**.5 in screws**		**.75-inch screws**	
.75*Fnv*Ab bolts	6.52905175	kip	14.6903664	kip
Fnv= Nominal Shear strength ksi				
Fnt=.75*Fu found in section c-j3-2	43.5			
When threads are excluded from the shear planes (C-J3-3)				
Fnv=.563Fu	44.3	KSI		
When threads are not excluded from the shear plane (C-J3-4)				

Fnv=.45Fu	35.4	KSI		
Capacity P=St*Ab	0.5	inch	0.75	inch
	20.6	kip	46.4	kip

`

13.9 Appendix I: Shop Drawings

Shop Drawings are attached at the end of the document

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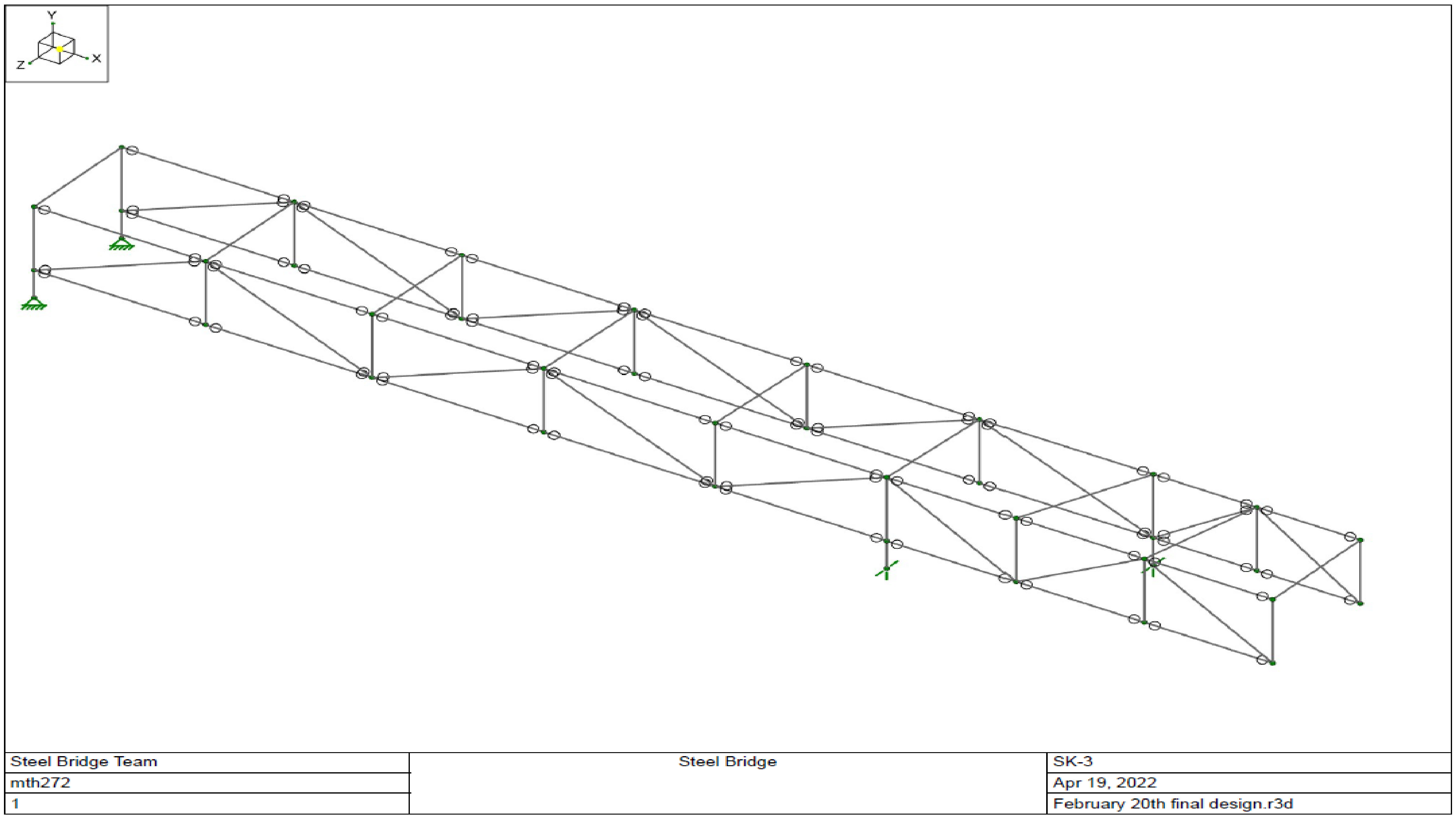
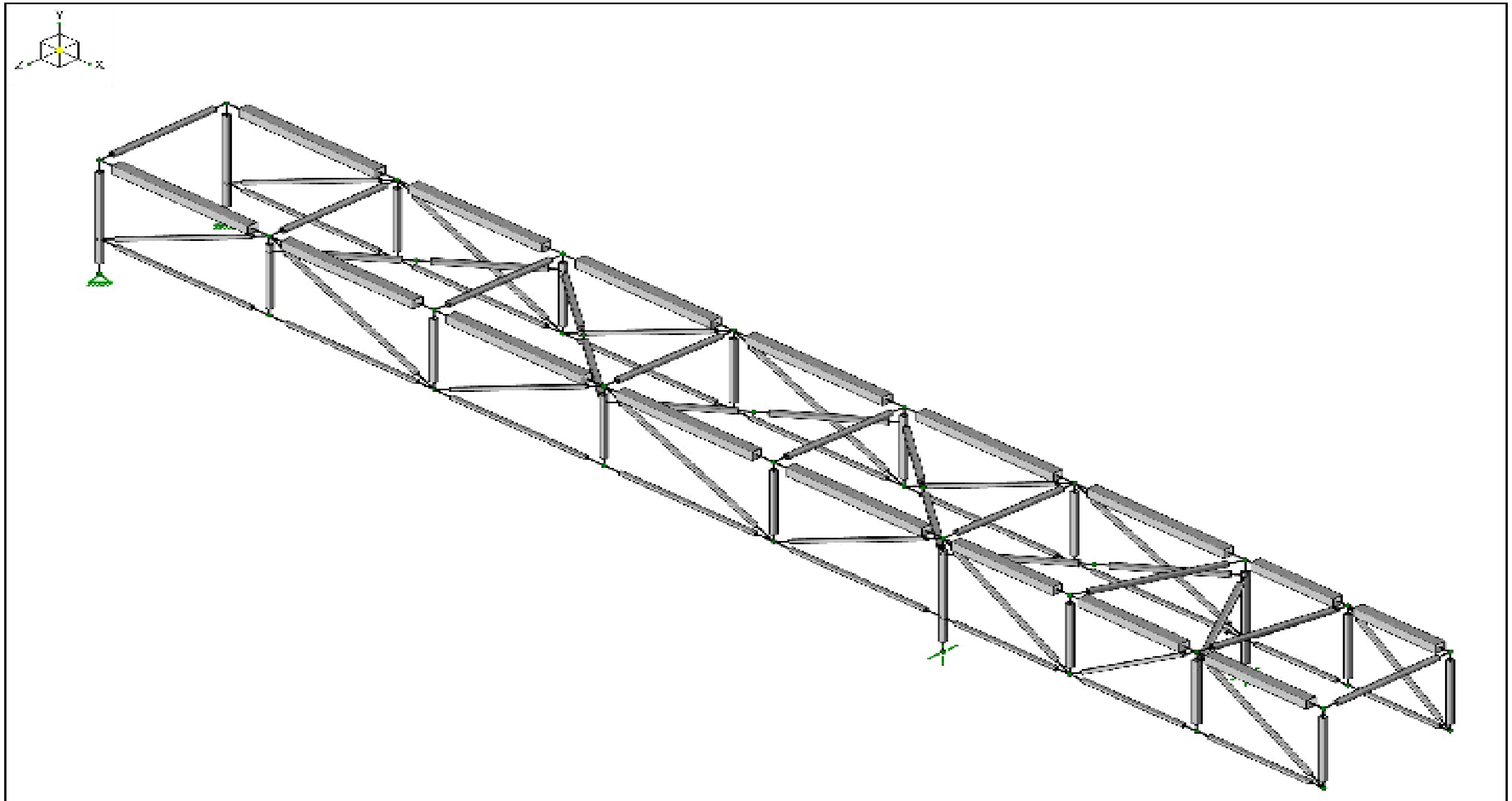
13.10 Appendix J: Final RISA Model





Steel Bridge Team	Steel Bridge	SK-2
mth272		Apr 18, 2022
1		March 6th final design.r3d

`

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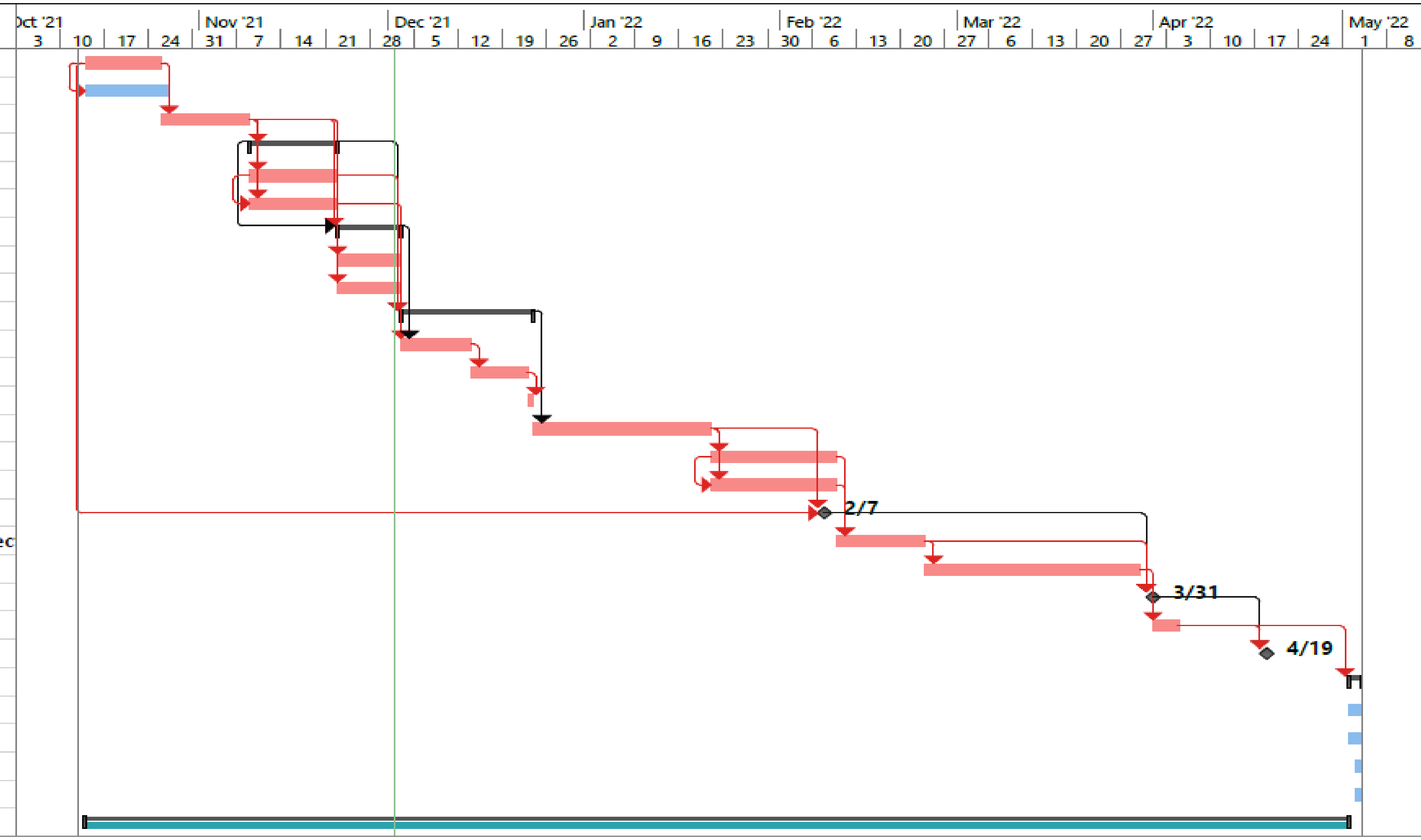
13.11 Appendix K: Proposal Schedule

ID	Task Mode	Task Name
1		**Competition Due Diligence**
2		**Impact Analysis**
3		**Conduct Material Research**
4		**Research Potential Bridge Design**
5		Cantilever Design
6		Member Design
7		**Conduct Connections Design Research**
8		Material Specifications
9		Connection Schematics
10		**Conduct Modelling and Analysis of Design**
11		Loading Calculations
12		Calculate Stress and Strain Values
13		Log Data of Tensile Tests
14		**Shop Drawings**
15		**Coordinated Assembly: Member Fabrication**
16		**Coordianted Assembly: Connection Fabrication**
17		30 Percent Deliverable
18		**Team Assembly: Modifications and Member Connec**
19		**Team Assembly Construction Practice**
20		60 percent Deliverble
21		**Compete in Regional Competition**
22		90 Percent Deliverable
23		**Project Deliverables**
24		Final Report
25		Plans
26		Product
27		Presentation
28		**Project Management**



Project: Schedule December 2,
Date: Thu 12/2/21

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

Page 1

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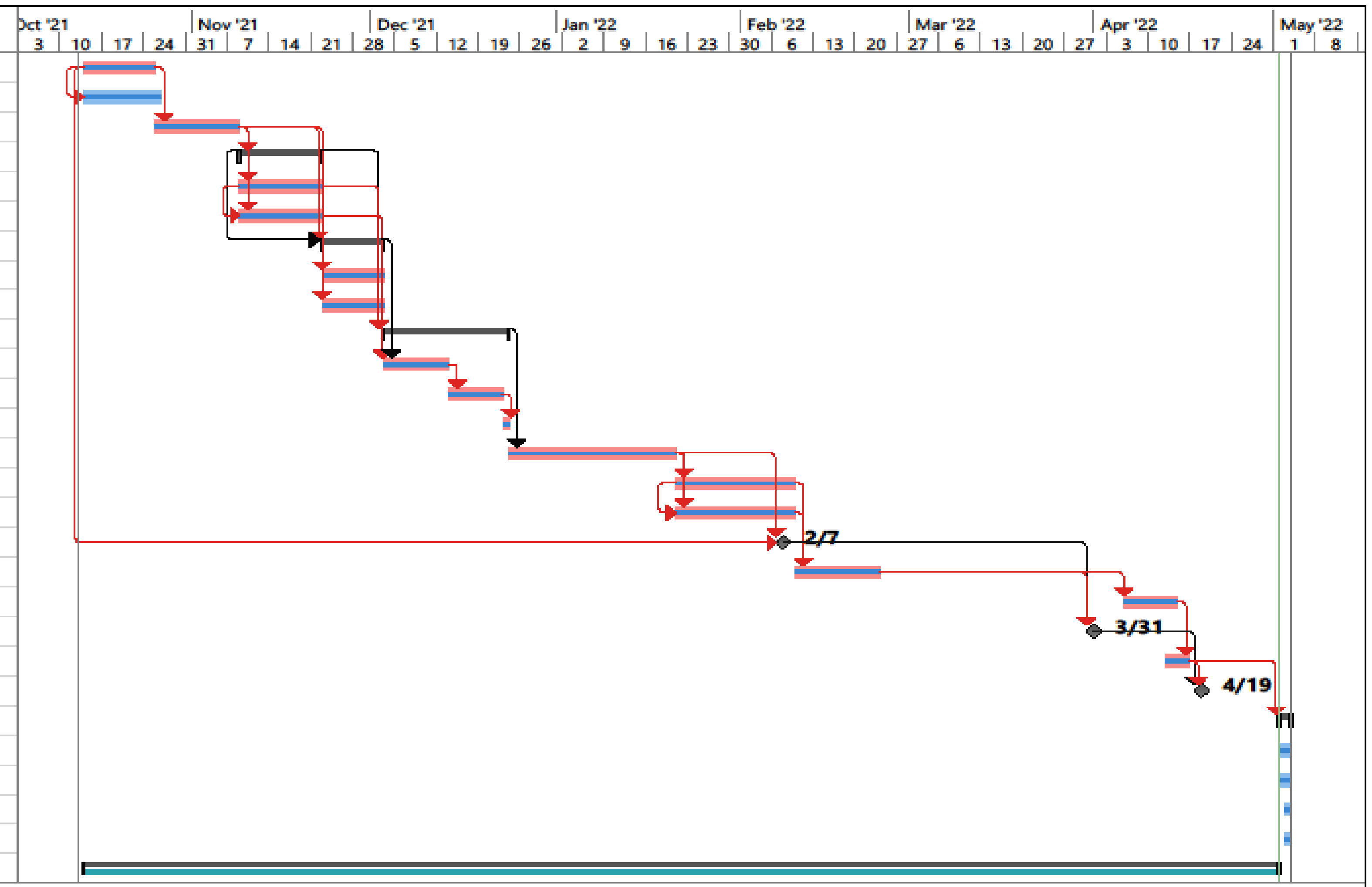
3.12 Appendix L: Final Schedule

ID	Task Name	Duration
1	**Competition Due Diligence**	8 days
2	**Impact Analysis**	9 days
3	**Conduct Material Research**	10 days
4	**Research Potential Bridge Design**	**10 days**
5	Cantilever Design	10 days
6	Member Design	10 days
7	**Conduct Connections Design Research**	**8 days**
8	Material Specifications	8 days
9	Connection Schematics	8 days
10	**Conduct Modelling and Analysis of Design**	**15 days**
11	Loading Calculations	7 days
12	Calculate Stress and Strain Values	7 days
13	Log Data of Tensile Tests	1 day
14	**Shop Drawings**	20 days
15	**Coordinated Assembly: Member Fabrication**	14 days
16	**Coordianted Assembly: Connection Fabrication**	14 days
17	**30 Percent Deliverable**	0 days
18	**Team Assembly: Modifications and Member Connec**	10 days
19	**Team Assembly Construction Practice**	7 days
20	**60 percent Deliverble**	0 days
21	**Compete in Regional Competition**	3 days
22	**90 Percent Deliverable**	0 days
23	**Project Deliverables**	**2 days**
24	Final Report	2 days
25	Plans	2 days
26	Product	1 day
27	Presentation	1 day
28	**Project Management**	**143 days**



Project: Schedule 30 percent
Date: Mon 5/2/22

Task | Inactive Task | Manual Summary Rollup | External Milestone
Split | Inactive Milestone | Manual Summary | Deadline
Milestone | Inactive Summary | Start-only | Progress
Summary | Manual Task | Finish-only | Manual Progress
Project Summary | Duration-only | External Tasks

Page 1

13.13 Appendix M: Engineering Costs

Task	Personnel						SUM
	SENG	PENG	EIT	INT	DRF	ADM	
Task 1: Competition Due Diligence	2	2	4	4	0	4	16
Task 2: Impact Analysis	1	1	3	3	0	4	12
Task 3: Conduct Material Research	0	3	8	6	0	8	25
Task 4: Research Potential Bridge Designs	0	4	10	10	0	10	34
Task 4.1: Cantilever Design	0	2	5	5	0	5	17
Task 4.2: Member Design	0	2	5	5	0	5	17
Task 5: Conduct Connections Design Research	8	10	15	15	0	0	48
Task 5.1: Material Specifications	4	5	10	10	0	0	29
Task 5.2: Connection Schematics	4	5	5	5	0	0	19
Task 6: Conduct Modelling and Analysis of Design	12	36	18	15	0	0	81
Task 6.1: Loading Calculations	4	12	6	5	0	0	27
Task 6.2: Calculate Stress and Strain Values	4	12	6	5	0	0	27
Task 6.3: Log Data of Tensile Tests	4	12	6	5	0	0	27
Task 7: Shop Drawings	4	2	0	0	35	0	41
Task 8: Coordinated Assembly: Member Fabrication	0	0	0	0	0	0	0
Task 9: Coordinated Assembly: Connection Fabrication	0	0	0	0	0	0	0
Task 10: Team Assembly: Modifications and Member Connection	5	10	50	20	0	0	85

`

Task 11: Team Assembly: Construction Practice	5	10	50	20	0	0	85
Task 12: Compete in Regional Competition	0	84	84	84	0	0	252
Task 13: Project Deliverables	7	19	70	21	0	14	131
Task 13.4: Final Report	1	5	10	3	0	2	21
Task 13.5: Plans	1	2	10	3	0	2	18
Task 13.6: Product	1	2	5	3	0	2	13
Task 13.7: Presentation	1	1	10	3	0	2	17
Task 14: Project Management	16	20	4	4	0	16	60
Task 14.1: Coordination of Teammates and Duties	10	14	1	1	0	4	30
Task 14.2: Steel Donation Contact	2	2	1	1	0	4	10
Task 14.3 Fabricator Contact	2	2	1	1	0	4	10
Task 14.4 Mentors Contact	2	2	1	1	0	4	10
Total	60	201	316	202	35	56	**870**

Cost of Engineering Services				
	Classification	Hours	Rate, $/hour	Cost
1.0 Personnel	SENG	60	170	$10,200.00
	PENG	201	150	$30,150.00
	EIT	316	50	$15,800.00
	INT	202	30	$6,060.00
	DRF	35	55	$1,925.00
	ADM	56	50	$2,800.00
	Personnel Total	870		$66,935.00

`

2.0 Materials	Steel members, connections and hardware				$31.07
3.0 Equipment	Tools required for construction and assembly				$1,039.37
4.0 Subcontract	Labor	120 hours	$0		$0.00
5.0 Travel	Van Rental	4 days	$65/day		$260.00
	Mileage	500 miles	$0.36/mile		$175.00
	Per Diem	4 days	$64/person/day	4 people	$1,024.00
	Lodging	3 nights	$118/room/night	2 rooms	$708.00
Total					**$137,107.44**

Member Schedule

Member Name	Material	Lengths	Quantity	Labels
Cantilever Leg	1"x1"x.065" Grade B A500 Steel Tube	26" typical	4	A
South Side Top Chords	2"x2"x.065" Grade B A500 Steel Tube	26"-34.8"	8	B1-B8
South Side Diagonal	.7"x.7"x.065" Grade B A500 Steel Tube	29.5'-37.6'	8	C1-C8
South Side Bottom Chords	.7"x.7"x.065" Grade B A500 Steel Tube	26"-34.8"	8	D1-D8
Vertical Supports	1"x1"x.065" Grade B A500 Steel Tube	17.8" typical	14	E
North Side Top Chords	2"x2"x.065" Grade B A500 Steel Tube	21"-35"	8	F1-F8
North Side Diagonal	.7"x.7"x.065" Grade B A500 Steel Tube	25.6"-37.8"	8	G1-G8
North Side Bottom Chords	.7"x.7"x.065" Grade B A500 Steel Tube	20.5"-35"	8	H1-H8
Top Laterals	1"x1"x.065" Grade B A500 Steel Tube	24"-24.4"	9	I1-I9
Diagonal Laterals	.7"x.7"x.065" Grade B A500 Steel Tube	21.5"-30.4"	11	J1-J11

Member Lengths

Bridge Part	B	C	D	F	G	H	I	J
1	34.8"	37.1"	33.8"	35.0"	37.3"	34.0"	24"	21.5"
2	33.8"	36.5"	33.8"	34.0"	36.9"	34.0"	24"	21.5"
3	34.8"	37.6"	34.8"	35.0"	37.1"	35.0"	24"	21.6"
4	34.8"	37.5"	34.8"	35.0"	37.8"	35.0"	24"	21.6"
5	34.8"	37.6"	34.3"	35.0"	37.8"	35"	24"	22"
6	26"	29.9"	25.5"	35.0"	37.7"	34.5"	24"	22"
7	26"	29.9"	26"	21.0"	26.0"	20.5"	24.4"	21.4"
8	26"	29.5"	26"	21.0"	25.6"	21.0"	24.4"	21.4"
9							24"	22.2"
10								22.2"
11								30.4"

~SHEET~ 1 OF 1

Northern Arizona University
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REVISIONS NO.	DATE	COMMENTS
1	4/19/22	
X	X/XX/XX	
X	X/XX/XX	

DRAWN BY: CHRISTIAN-GUNDERSON
CHECKED BY: MCKENNA-HUGES

DATE: APRIL-19TH-2022
SCALE: 1:4

STEEL-BRIDGE
SOUTHSIDE-MEMBER-SCHEDULE

Connection Schedule

Part	Material	Quantity	
ss1	11 gage	1	7
ss2	11 gage	1	10
ss3	11 gage	1	11
ss4	11 gage	1	14
ss5	11 gage	1	4
ss6	11 gage	1	16
ss7	11 gage	1	17
ss8	11 gage	2	20,42
ns1	11 gage	1	27
ns2	11 gage	1	30
ns3	11 gage	1	31
ns4	11 gage	1	34
ns5	11 gage	1	35
ns6	11 gage	1	23
ns7	11 gage	1	37
ns8	11 gage	2	40,41
Connection 1	11 gage	24	1,23,7,27,49,54,58,57,60,15,24,17,37,9,29,11,31,13,33,4,35,19,39
Connection 2	11 gage	6	9,29,13,33,15,24
Connection 3	11 gage	7	8,12,18,28,32,36,38
Connection 4	11 gage	4	1,23,19,39
Connection 5	11 gage	1	5
Connection 6	11 gage	4	1,23,19,39
Connection 7	11 gage	4	1,23,19,39
Connection 8	11 gage	7	55,53,50,46,59,47,56

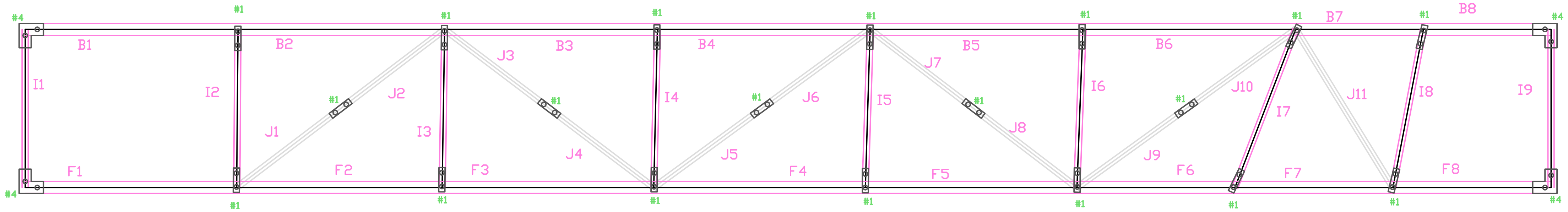
~SHEET~
1 OF 1

Northern Arizona University
College of Engineering, Informatics and Applied Sciences

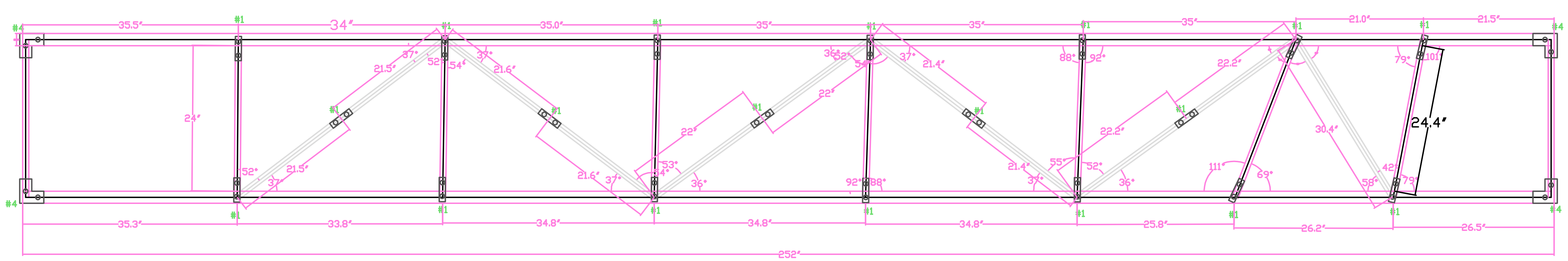
REVISIONS NO.	DATE	COMMENTS
1	4/19/22	
X	X/XX/XX	
X	X/XX/XX	

DRAWN BY: CHRISTIAN-GUNDERSON
CHECKED BY: MCKENNA-HUGES
DATE: APRIL-19TH-2022
SCALE: 1:4

STEEL-BRIDGE
CONNECTION-SCHEDULE



TOP VIEW (W/DIAGONALS)



TOP VIEW (W/DIAGONALS)

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Northern Arizona University
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X	X/XX/XX	

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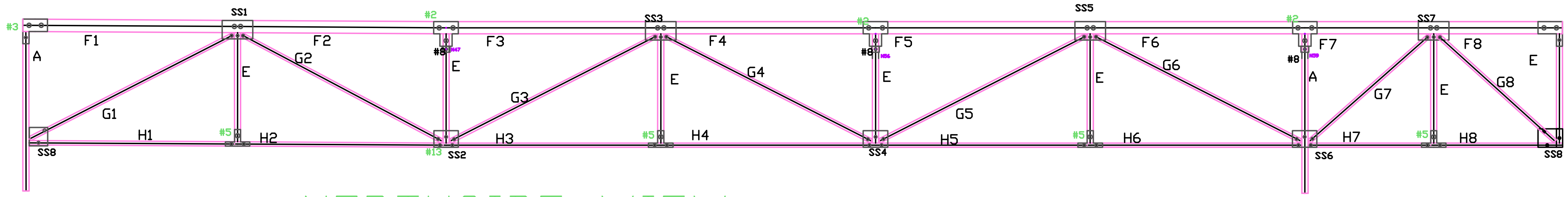
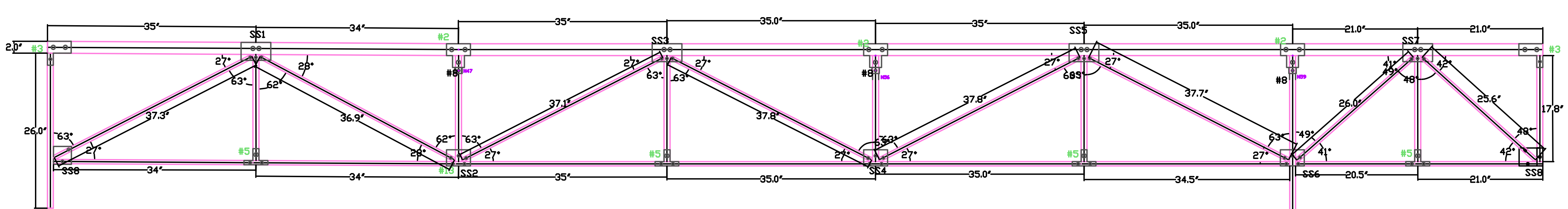
STEEL-BRIDGE
TOP-MEMBER-SCHEDULE



NORTHSIDE VIEW
(W/DIAGONALS)



NORTHSIDE VIEW
(W/DIAGONALS)

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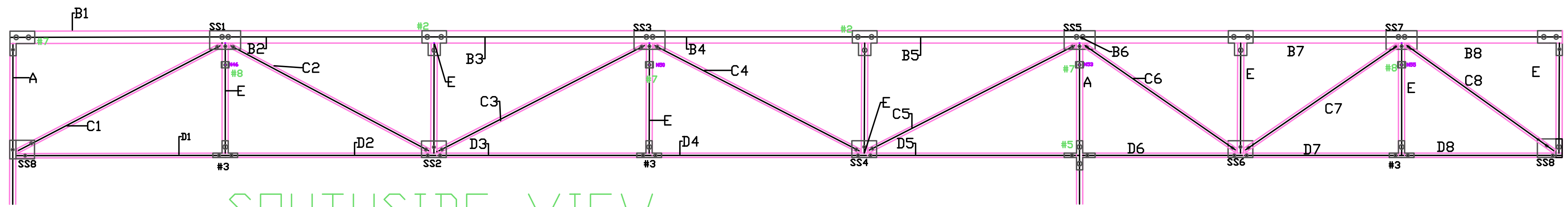
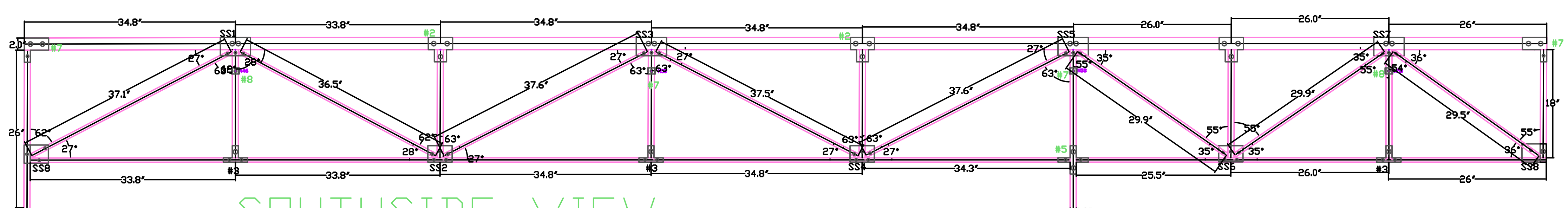
STEEL-BRIDGE
NORTH-MEMBER-SCHEDULE



SOUTHSIDE VIEW
(W/DIAGONALS)



SOUTHSIDE VIEW
(W/DIAGONALS)

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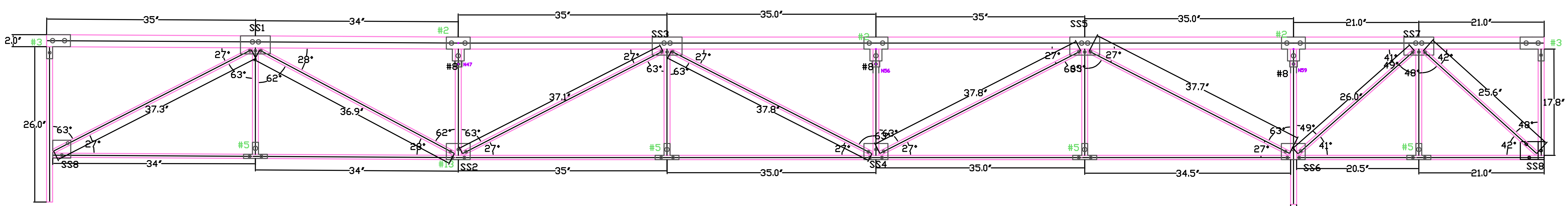
STEEL-BRIDGE
SOUTHSIDE-MEMBER-SCHEDULE



NORTHSIDE VIEW
(W/DIAGONALS)

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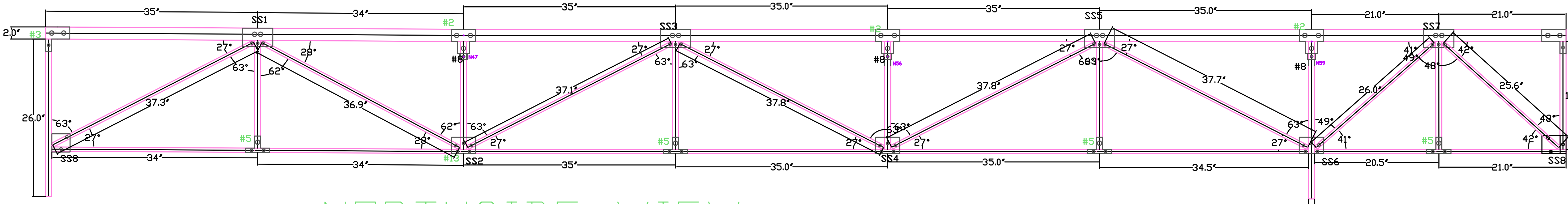
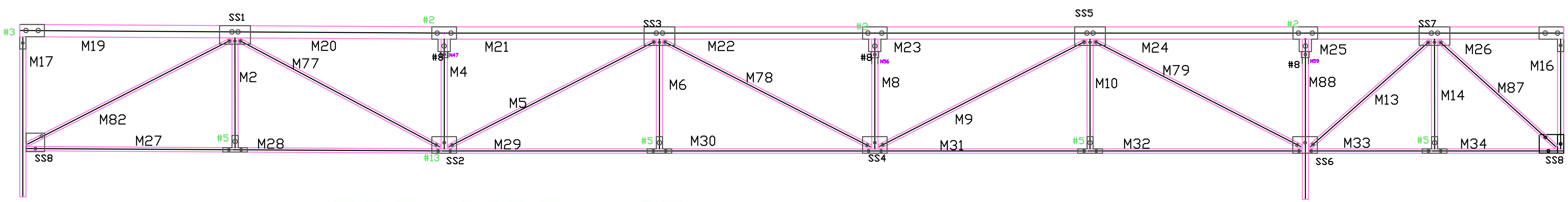
STEEL-BRIDGE
NORTH-SIDE



NORTHSIDE VIEW
(W/DIAGONALS)



NORTHSIDE VIEW
(W/DIAGONALS)

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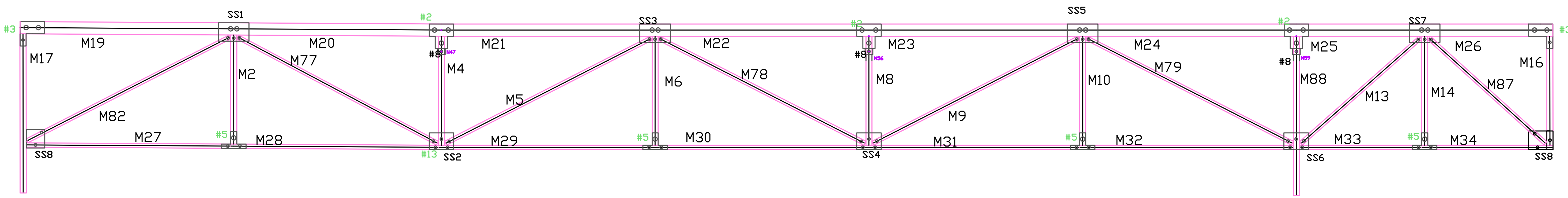
STEEL-BRIDGE
NORTH-SIDE



NORTHSIDE VIEW (W/DIAGONALS)

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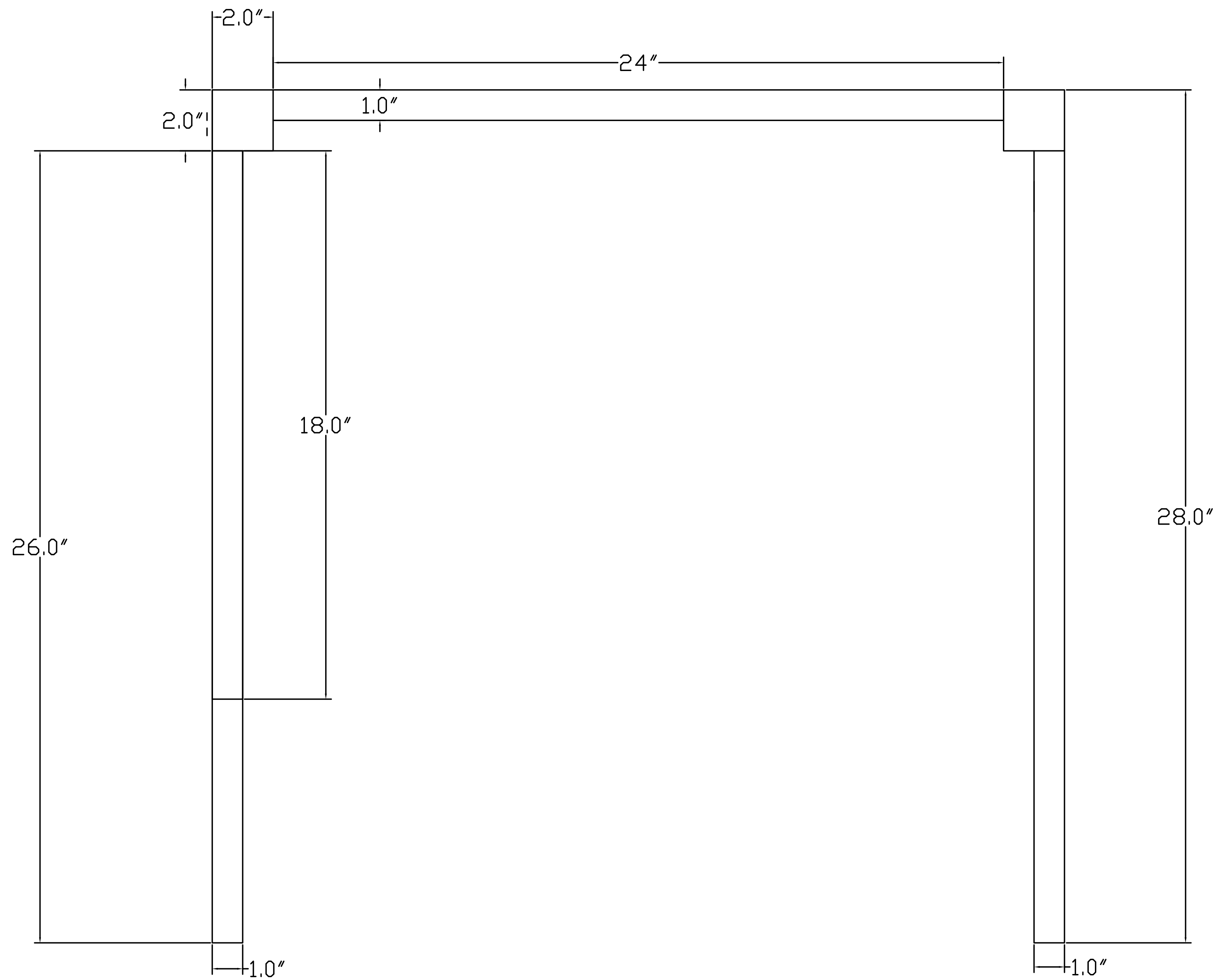
STEEL-BRIDGE
NORTH-SIDE



Side View with dimensions

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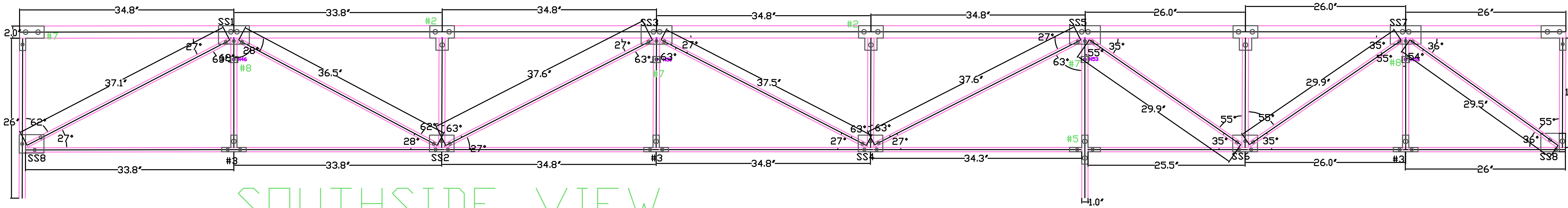
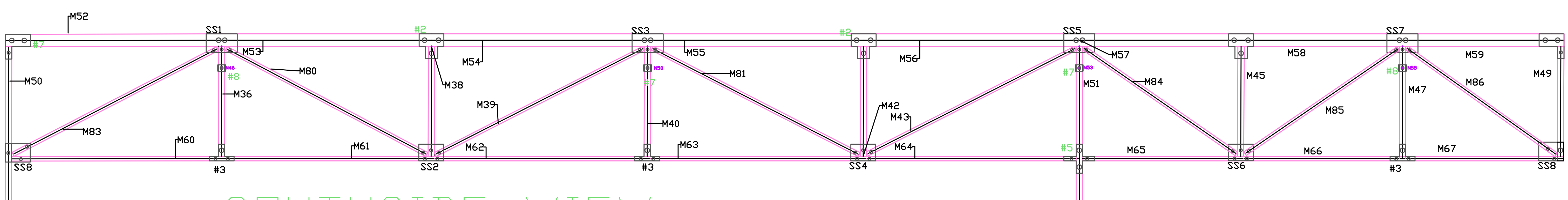
STEEL-BRIDGE
SIDE-VIEW



SOUTHSIDE VIEW
(W/DIAGONALS)



SOUTHSIDE VIEW
(W/DIAGONALS)

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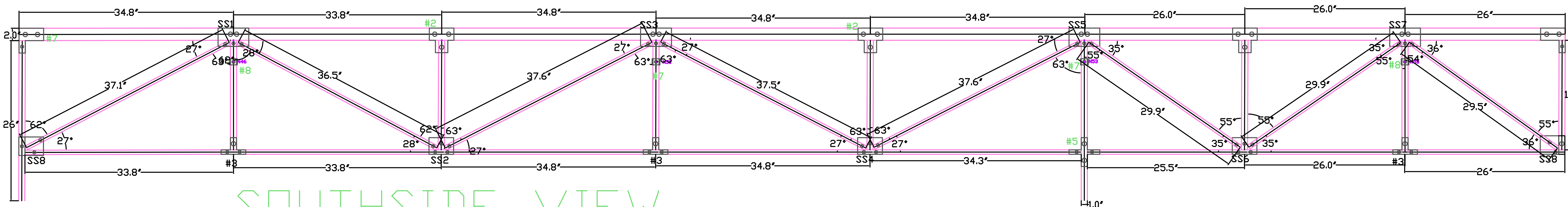
STEEL-BRIDGE
SOUTHSIDE-VIEWS



SOUTHSIDE VIEW
(W/DIAGONALS)

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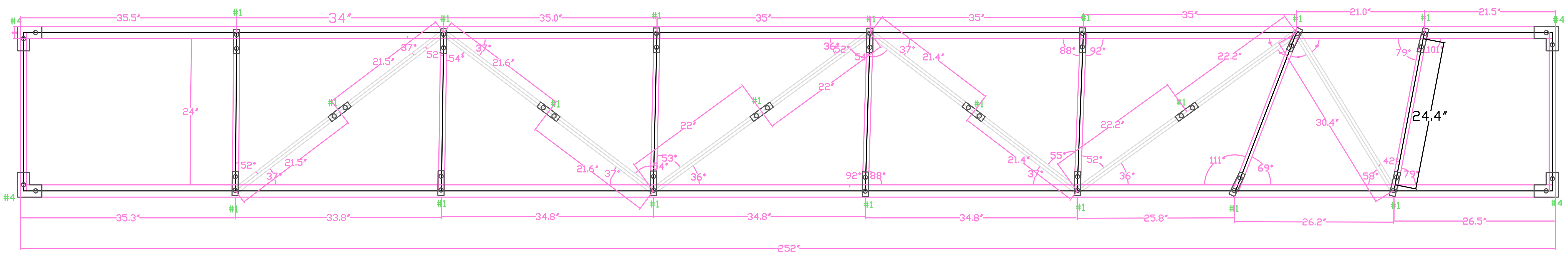
SCALE: 1:4

STEEL-BRIDGE
SOUTHSIDE-VIEWS



TOP VIEW (W/DIAGONALS)

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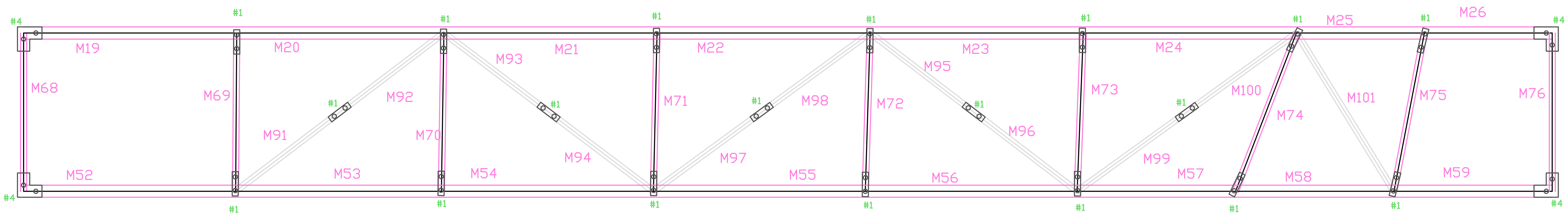
STEEL-BRIDGE
TOP-VIEW



TOP VIEW
(W/DIAGONALS)

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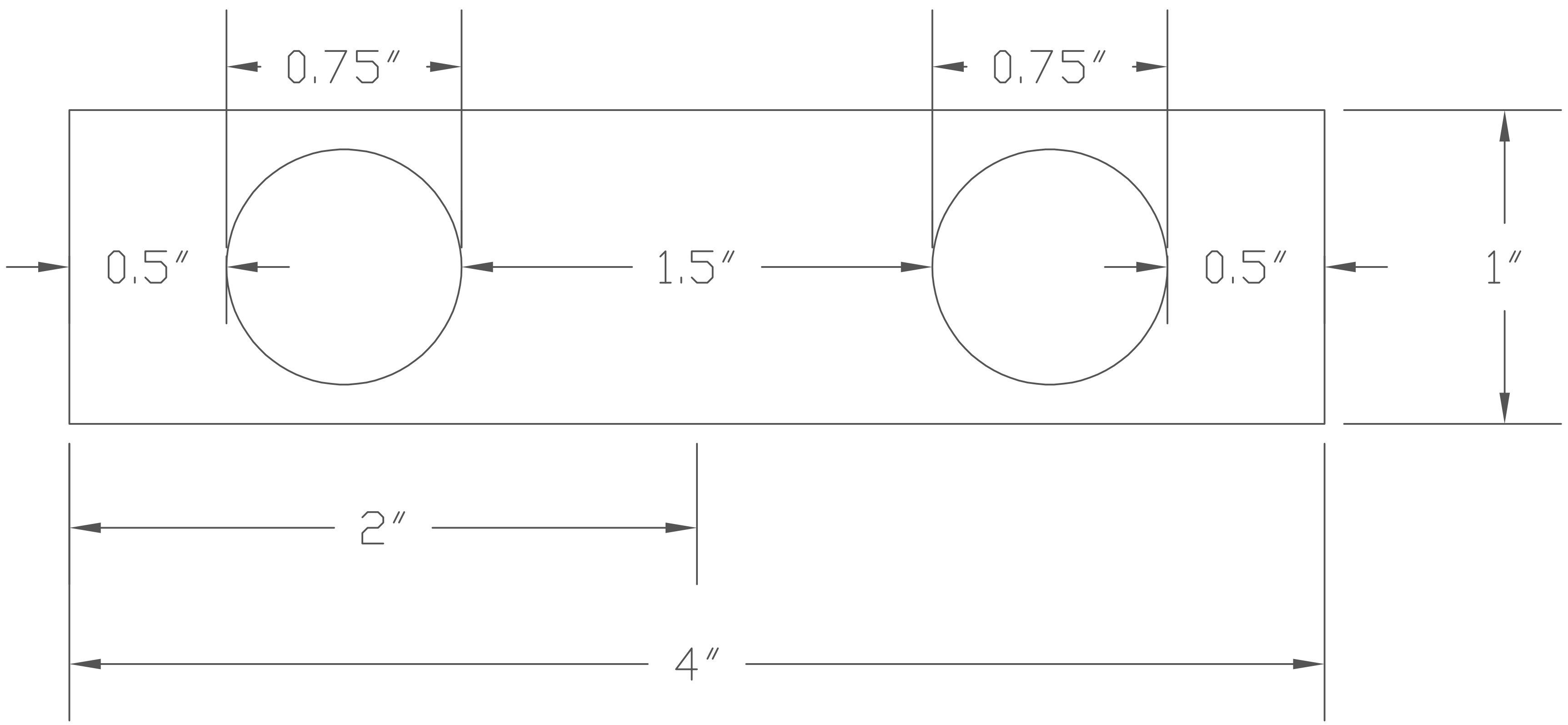
SCALE: 1:4

STEEL-BRIDGE
TOP-VIEW

Nodes:1,23,7,27,49,54,58,57,60,15
24,17,37,9,29,11,31,13,33,4,35,19,39



CONNECTION 1
Quantity 24

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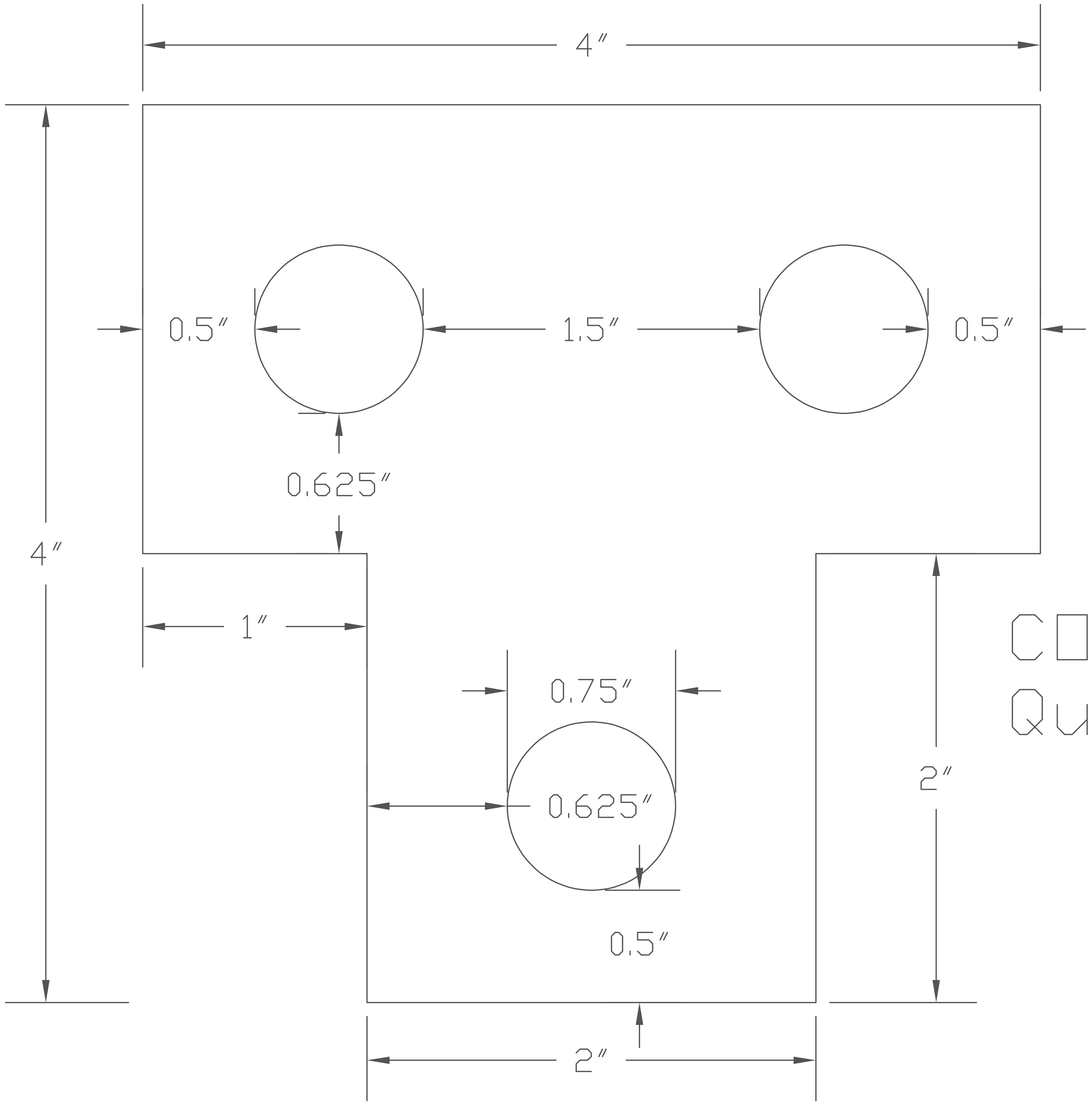
SCALE: 1:2

STEEL-BRIDGE
CONNECTION-SCHEMATICS

Nodes:9,29,13,33,15,24



CONNECTION 2
Quantity 6

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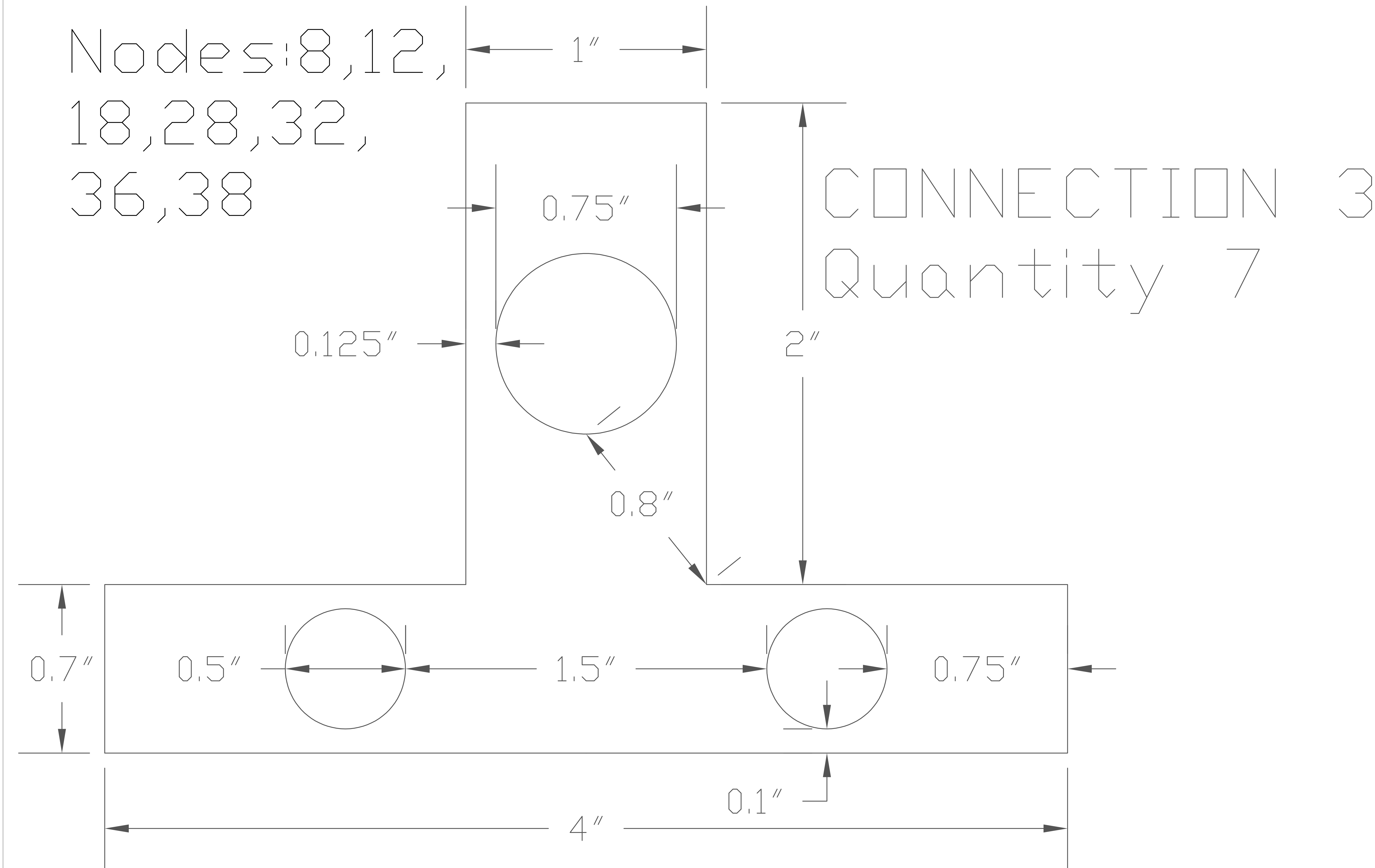
STEEL-BRIDGE
CONNECTION-SCHEMATICS



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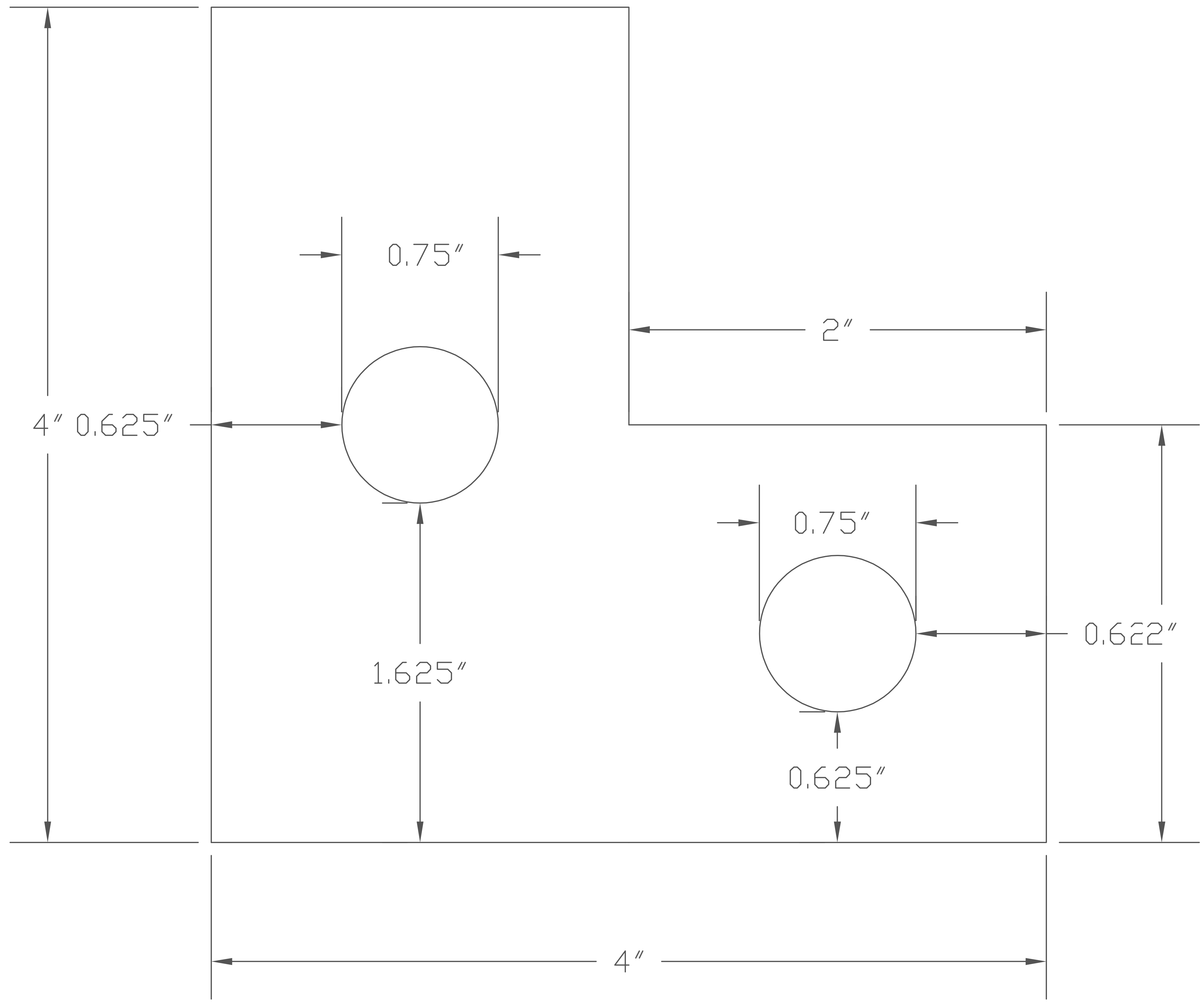
STEEL-BRIDGE
CONNECTION-SCHEMATICS

Nodes:1,
23,19,39

CONNECTION 4
Quantity 4



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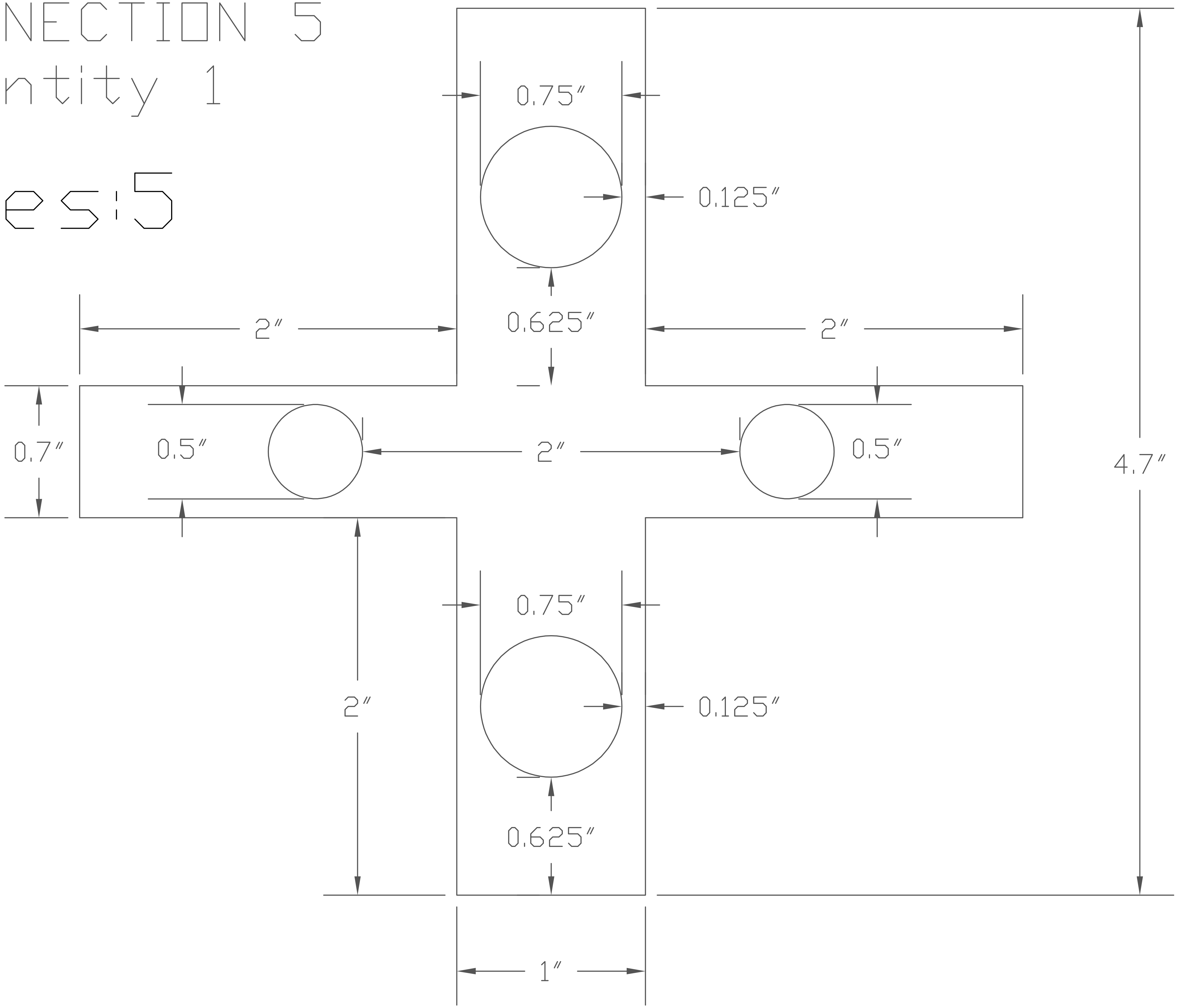
SCALE: 1:2

STEEL-BRIDGE
CONNECTION-SCHEMATICS

CONNECTION 5

Quantity 1

Nodes:5



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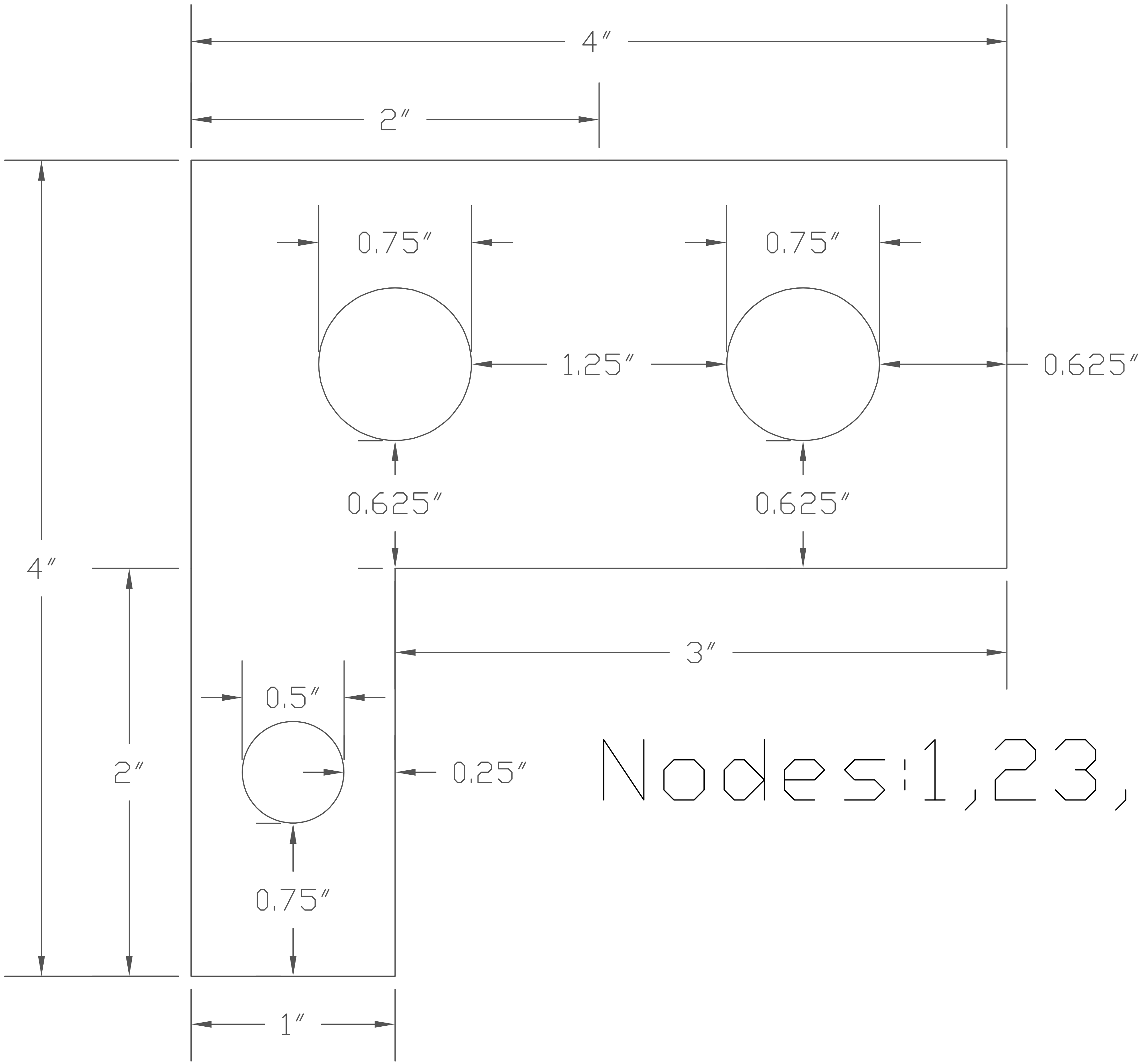
STEEL-BRIDGE
CONNECTION-SCHEMATICS

CONNECTION 6

Quantity 4



Nodes:1,23,19,39

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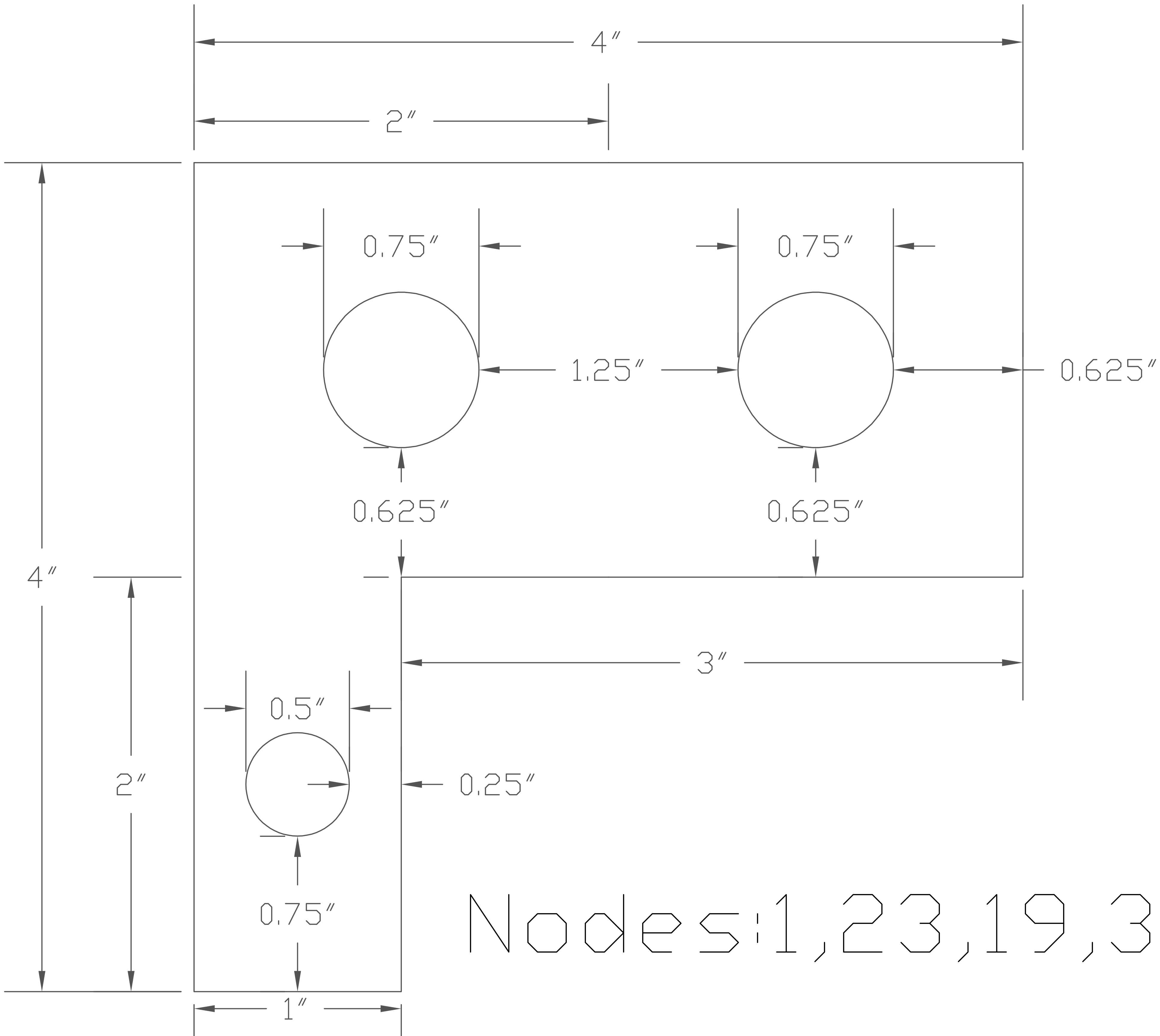
SCALE: 1:2

STEEL-BRIDGE
CONNECTION-SCHEMATICS

CONNECTION 7
Quantity 4



Nodes:1,23,19,39

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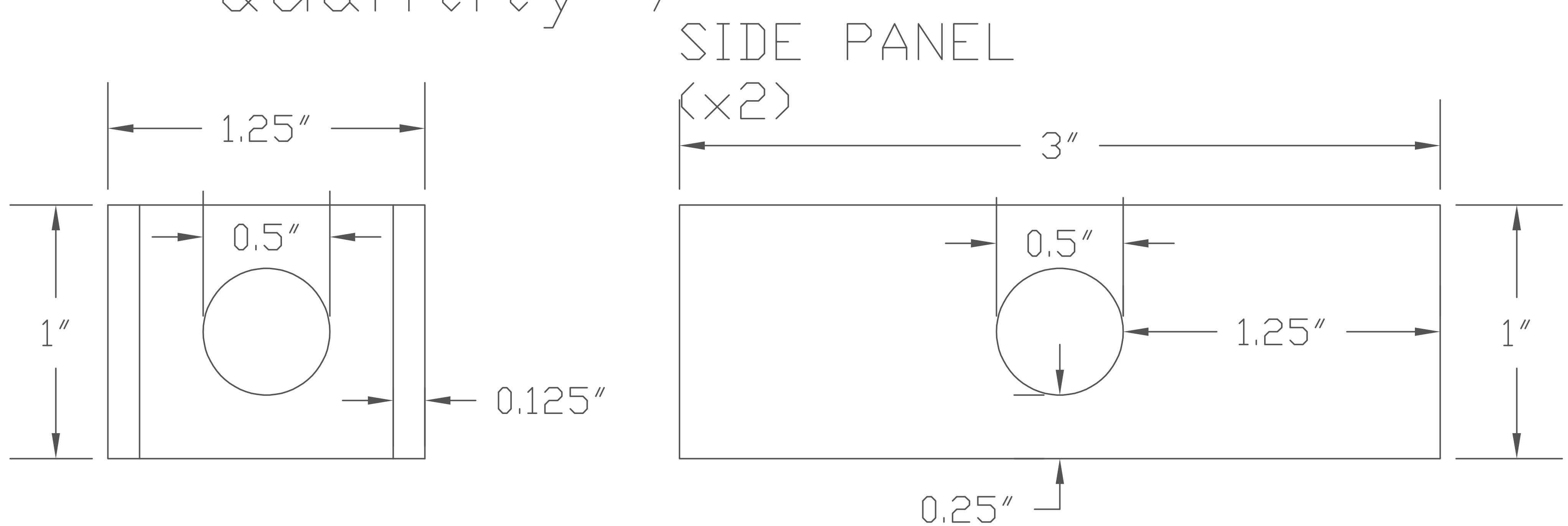
STEEL-BRIDGE
CONNECTION-SCHEMATICS

CONNECTION 8

Quantity 7



Nodes:55,59,53,56,50,47,46

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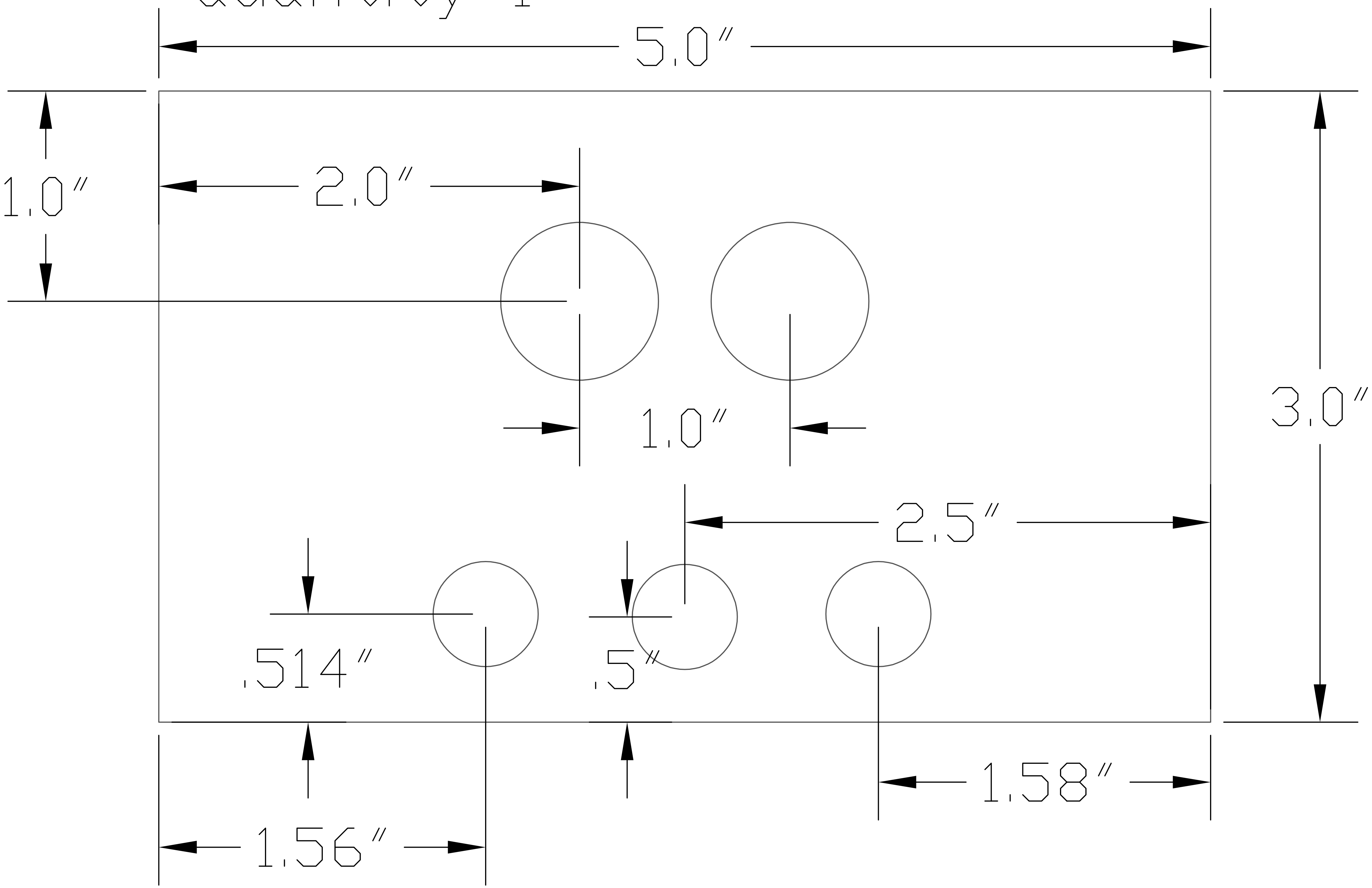
STEEL-BRIDGE
CONNECTION-SCHEMATICS

Nodes:27

North side 1
Quantity 1



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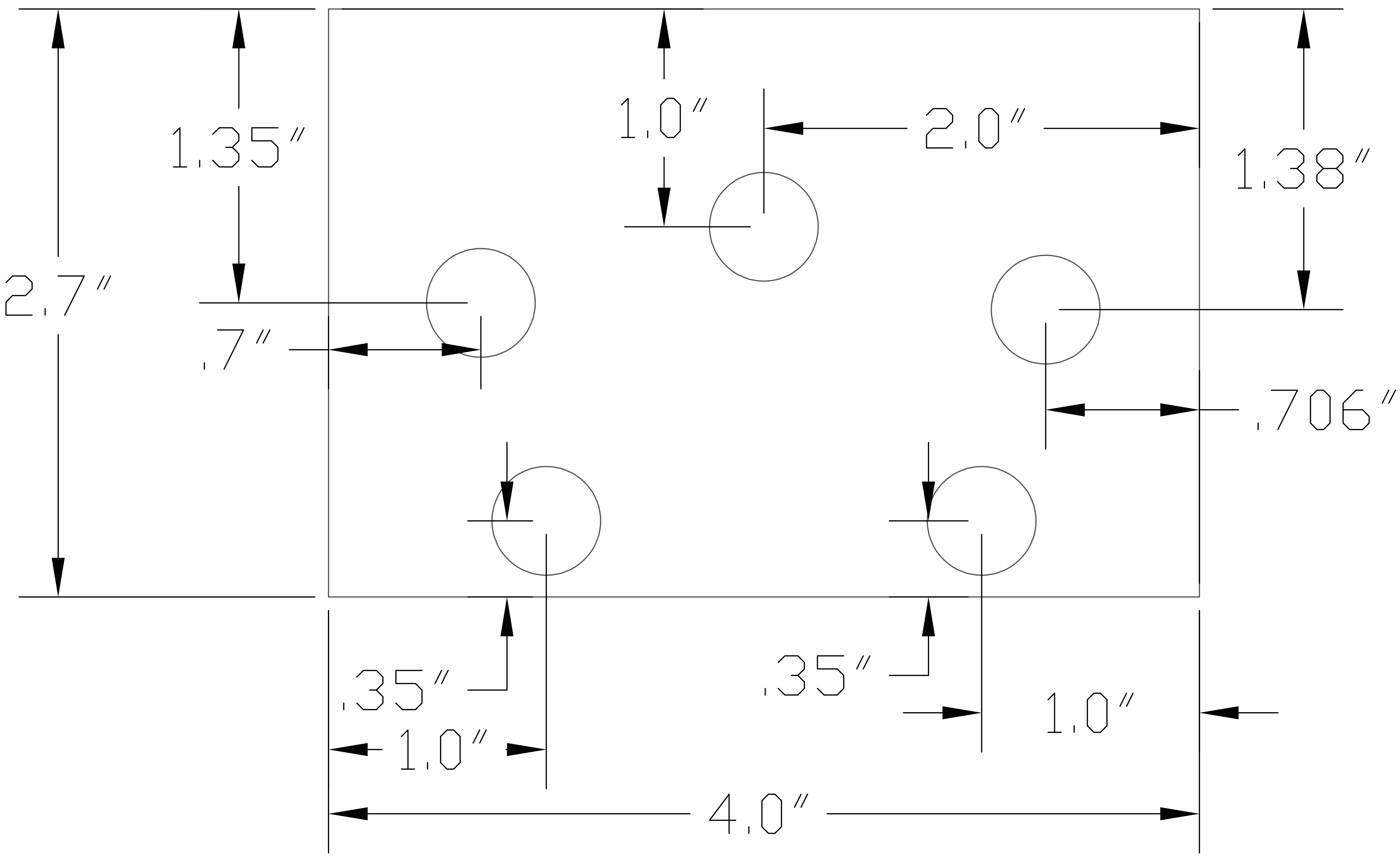
STEEL-BRIDGE
CONNECTION-SCHEMATICS

~SHEET~ 1 OF 1

Nodes:30

North Side 2
Quantity 1



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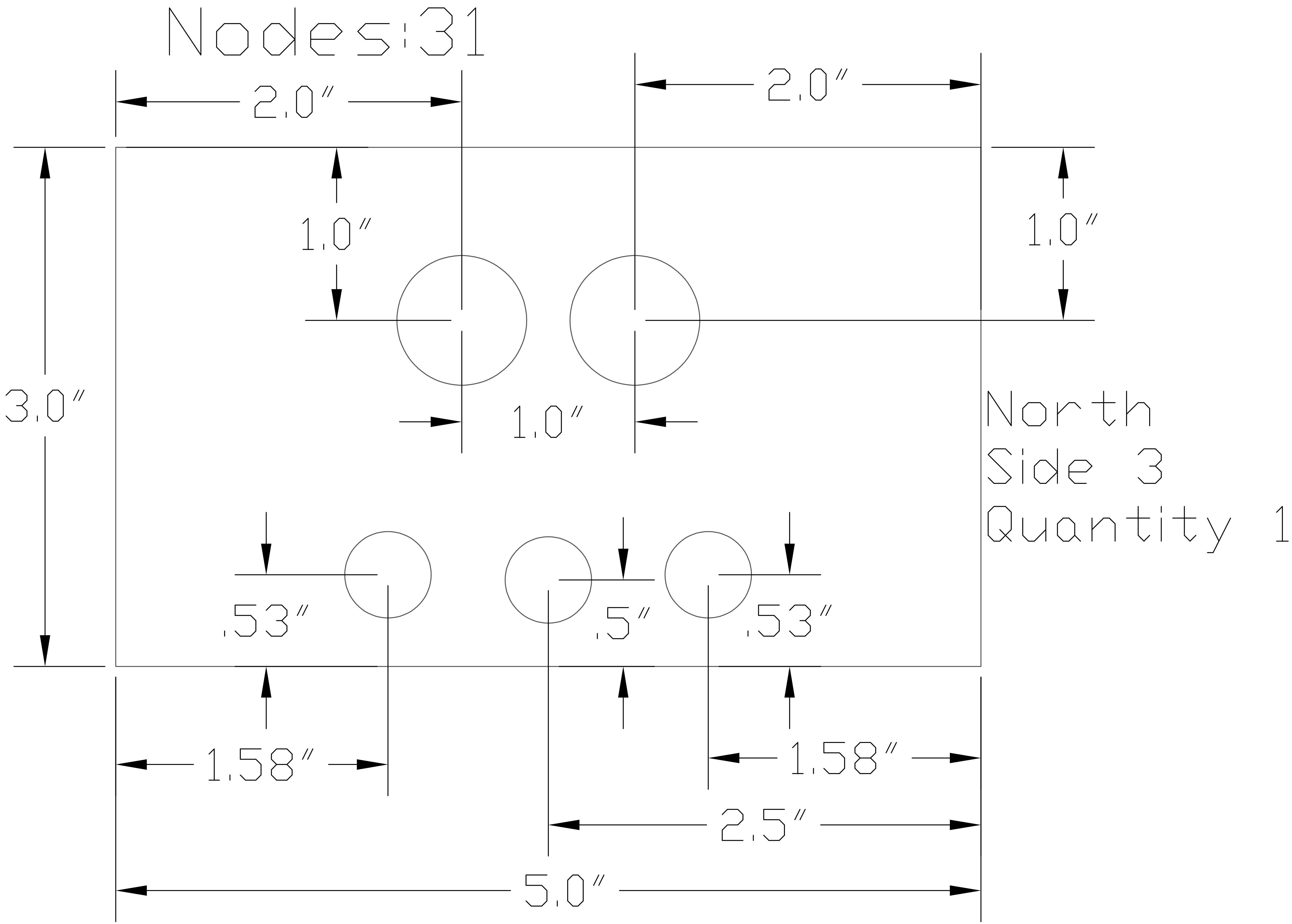
SCALE: 1:2

STEEL-BRIDGE
CONNECTION-SCHEMATICS



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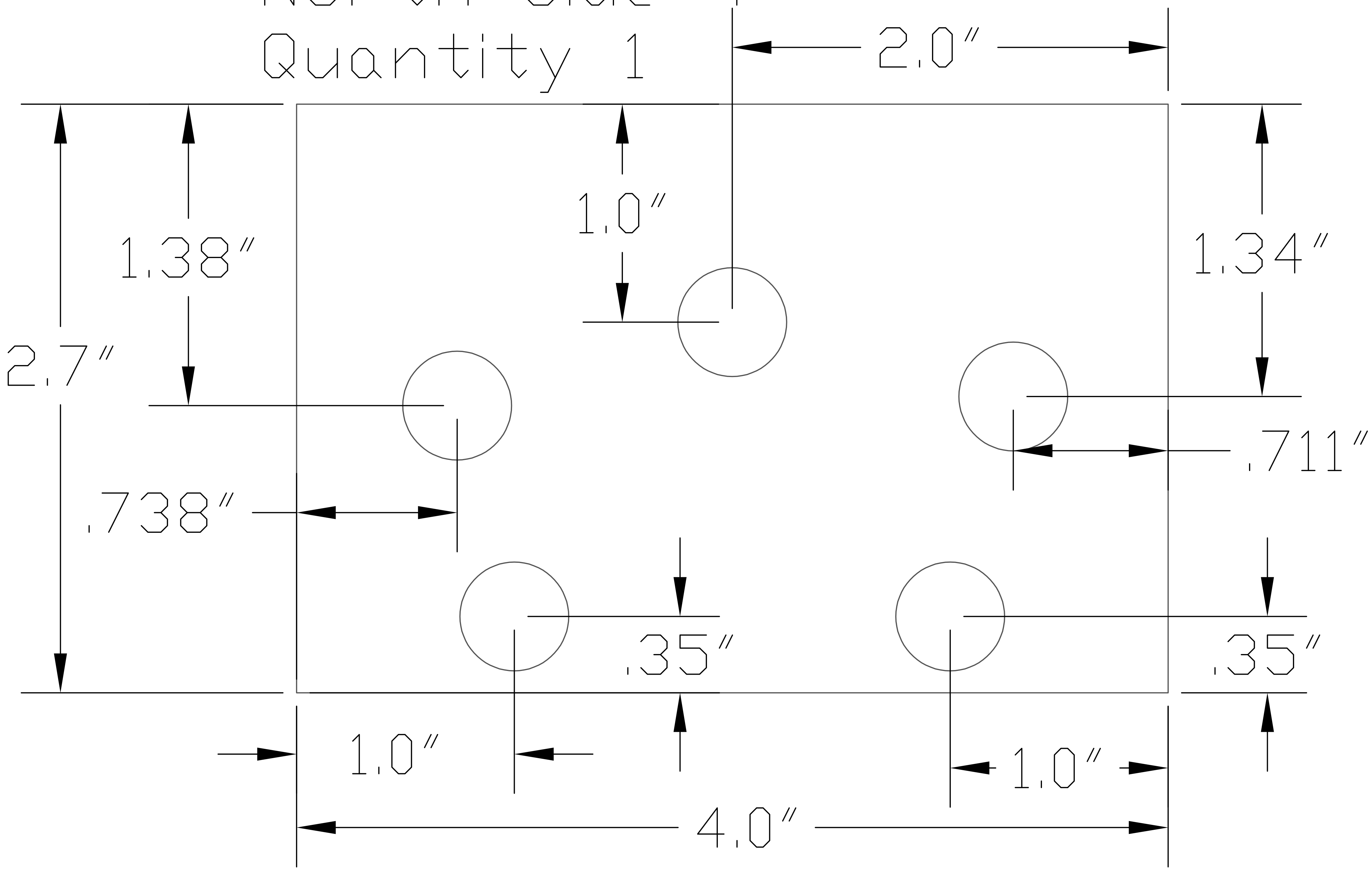
STEEL-BRIDGE
CONNECTION-SCHEMATICS

Nodes:34

North Side 4
Quantity 1



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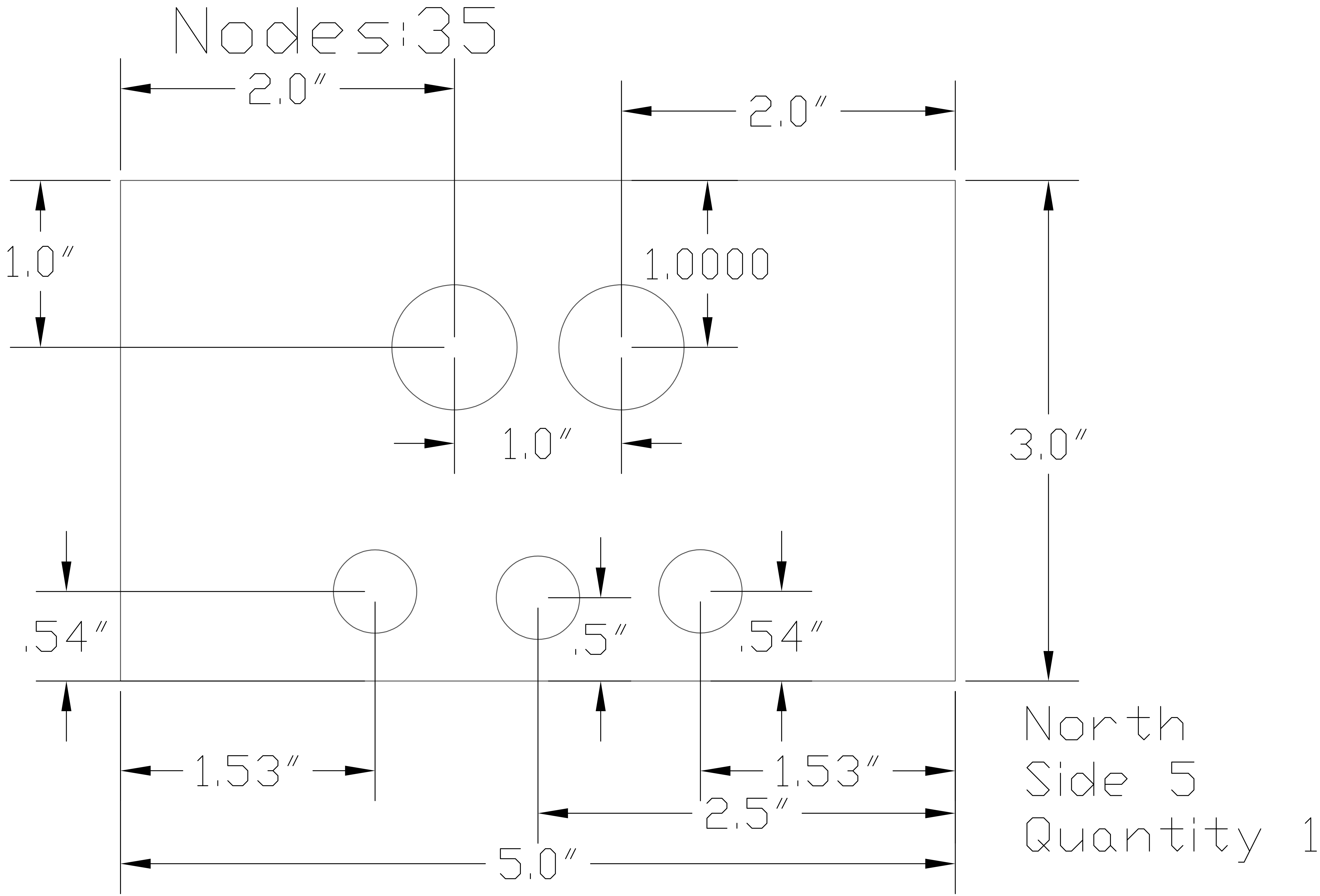
STEEL-BRIDGE
CONNECTION-SCHEMATICS



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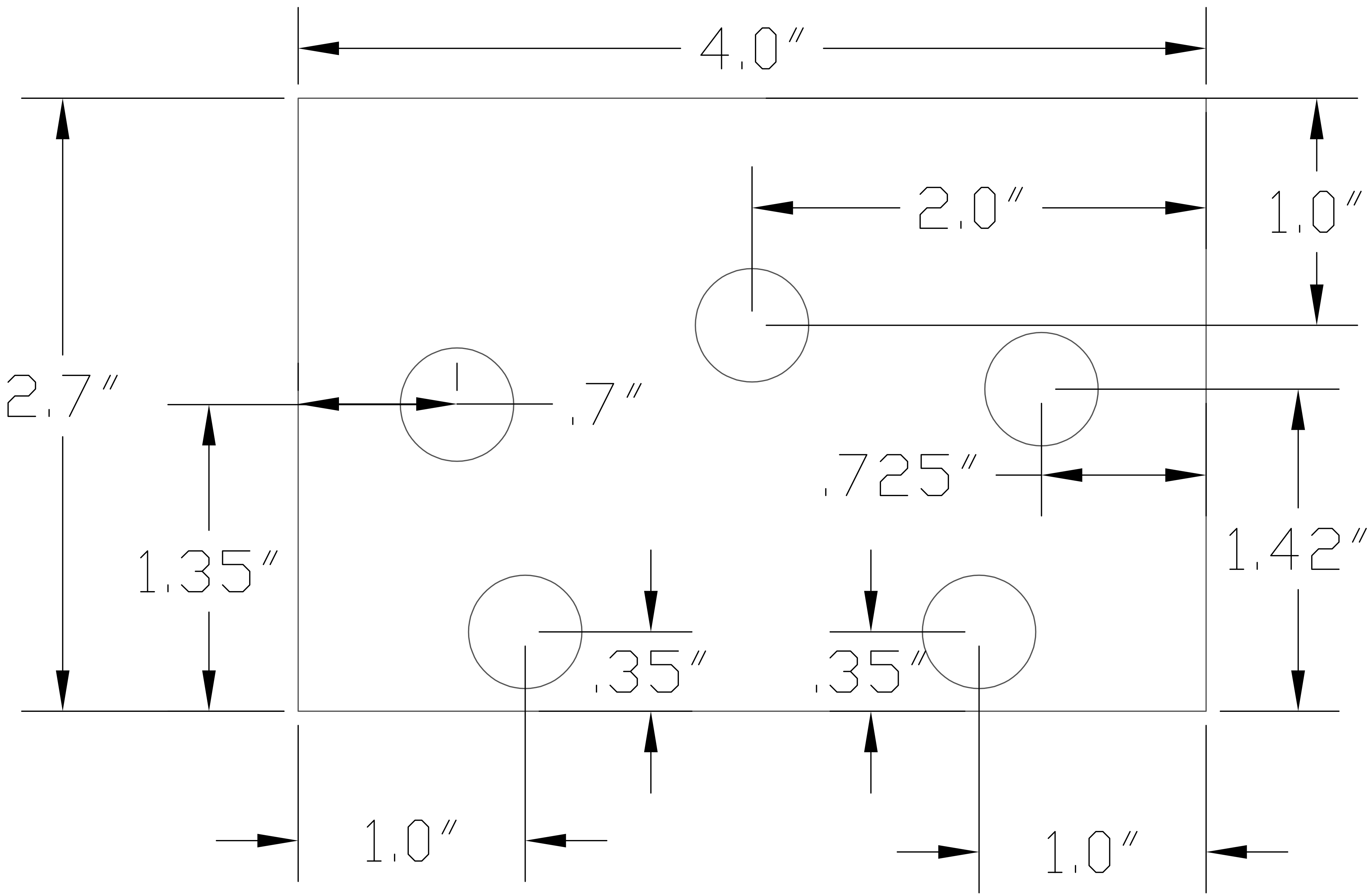
STEEL-BRIDGE
CONNECTION-SCHEMATICS

Nodes:25

North side 6

Quantity 1



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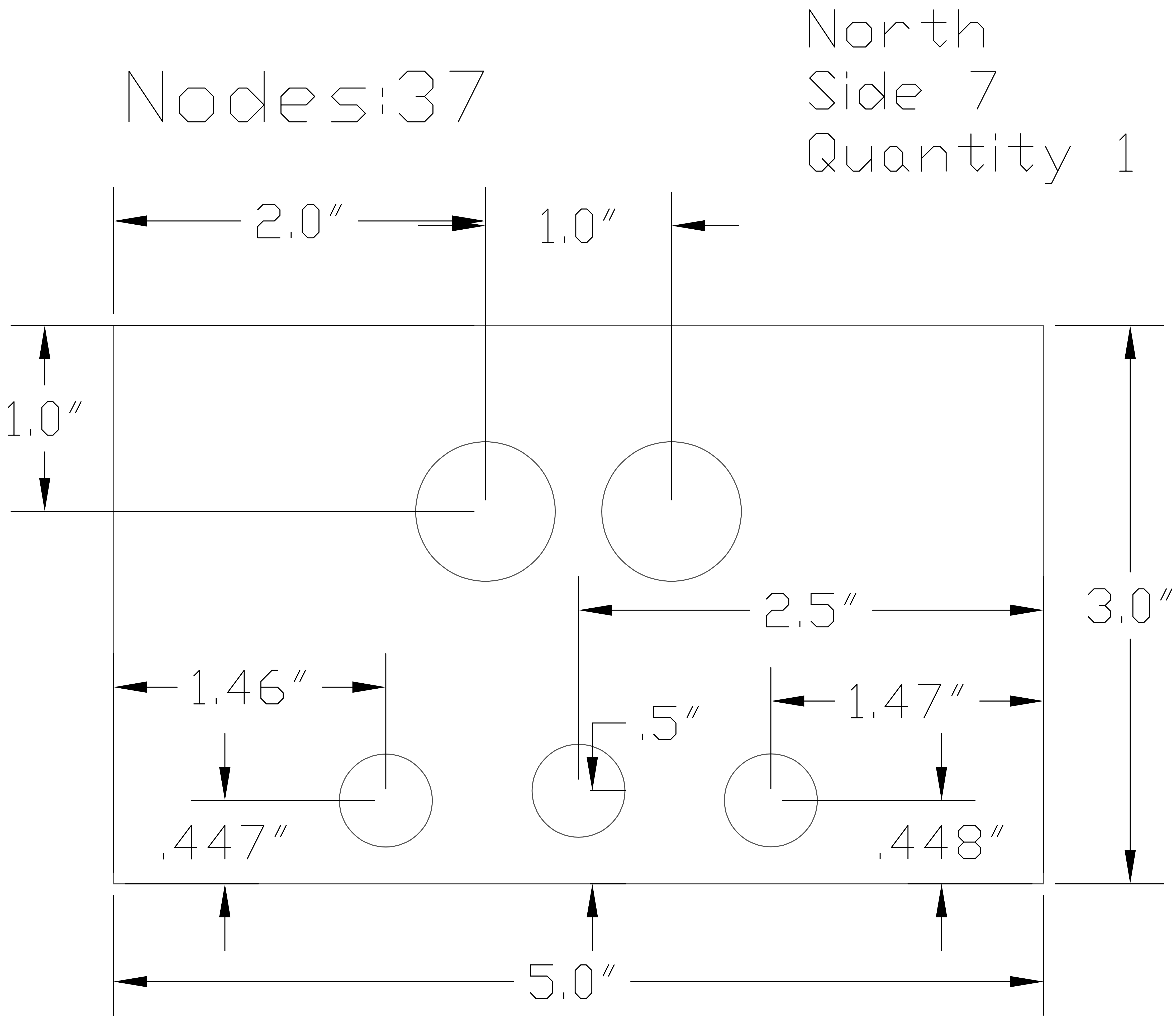
STEEL-BRIDGE
CONNECTION-SCHEMATICS



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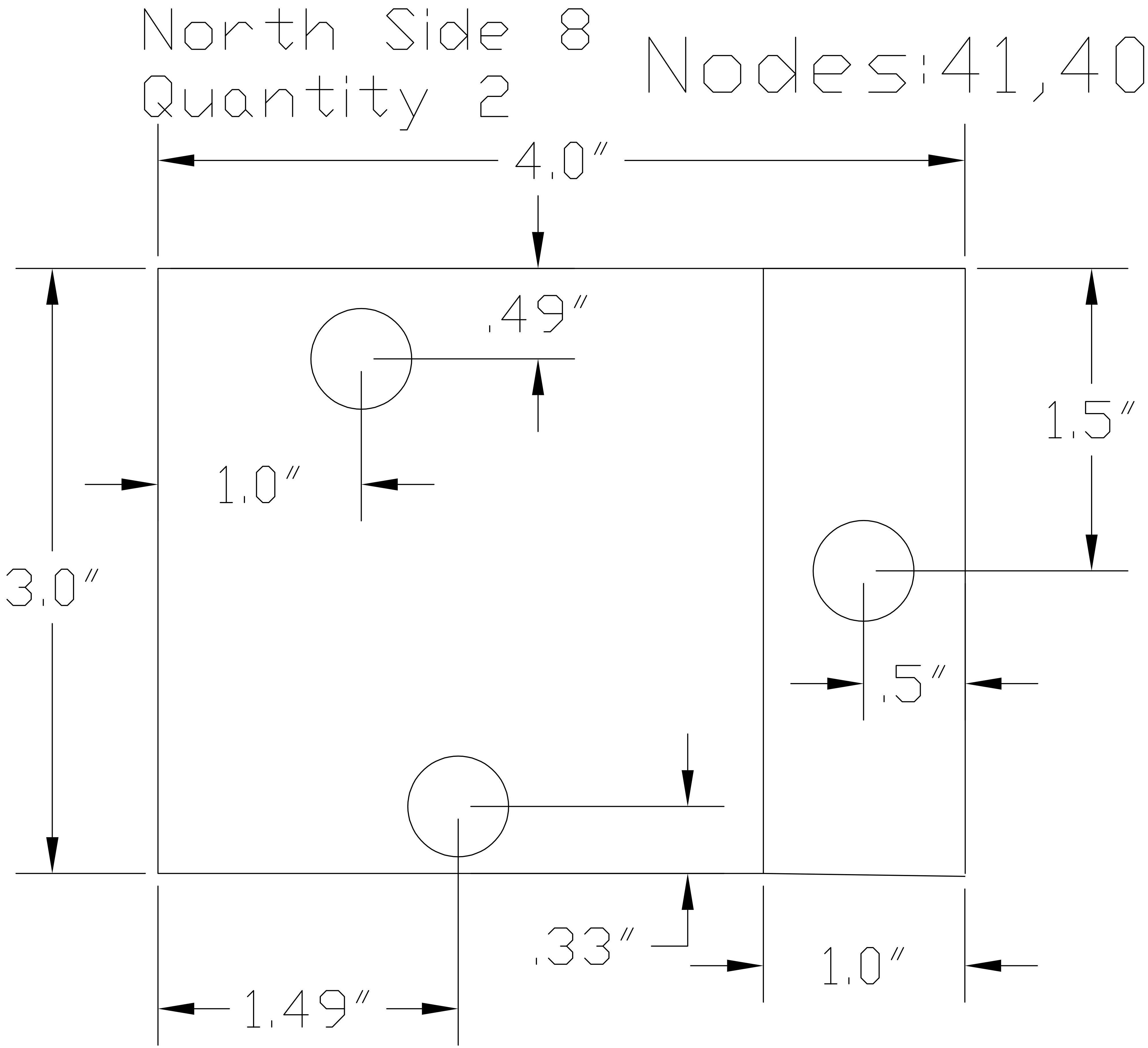
STEEL-BRIDGE
CONNECTION-SCHEMATICS



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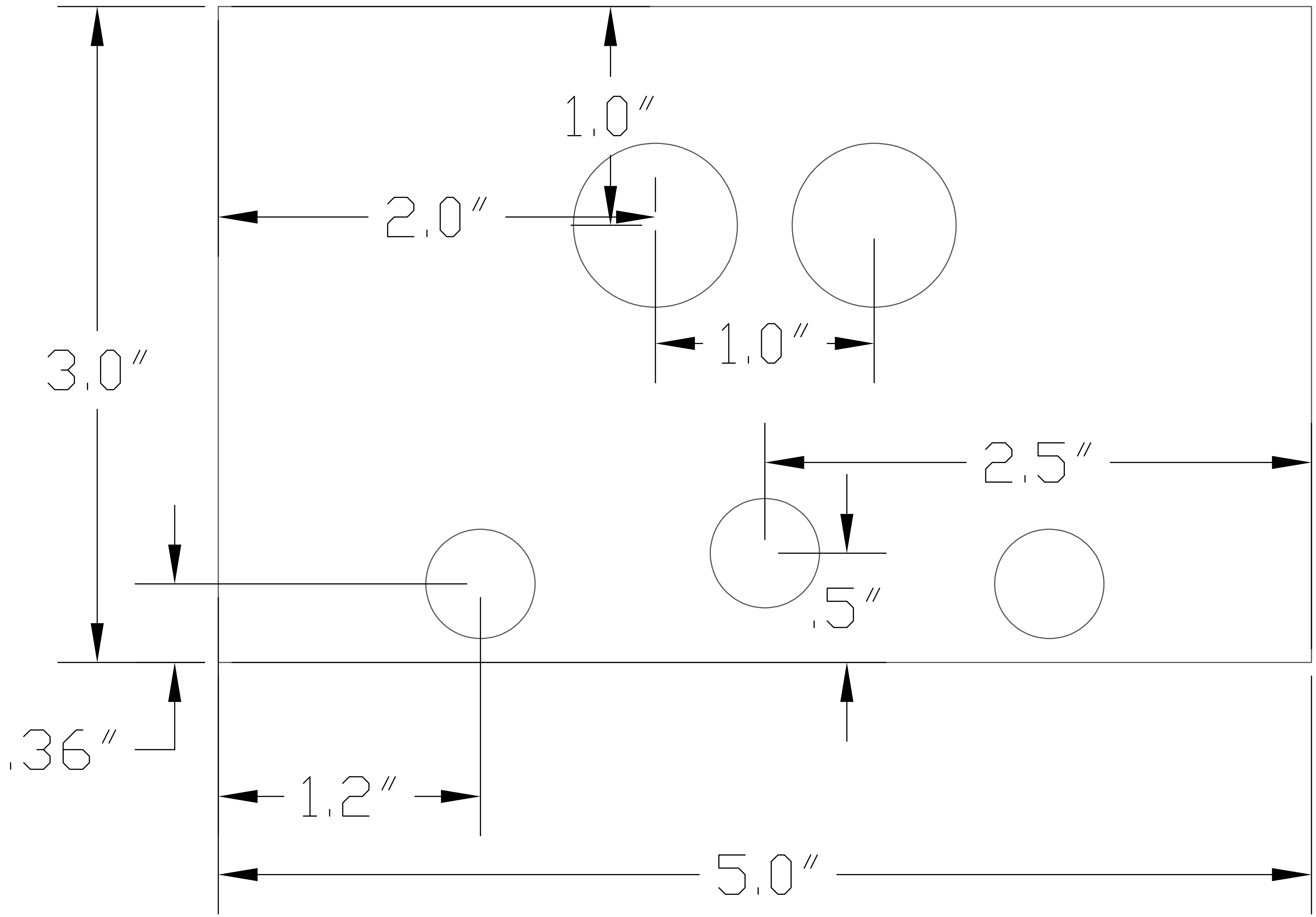
SCALE: 1:2

STEEL-BRIDGE
CONNECTION-SCHEMATICS

South side 1
Quantity 1

Nodes:
7



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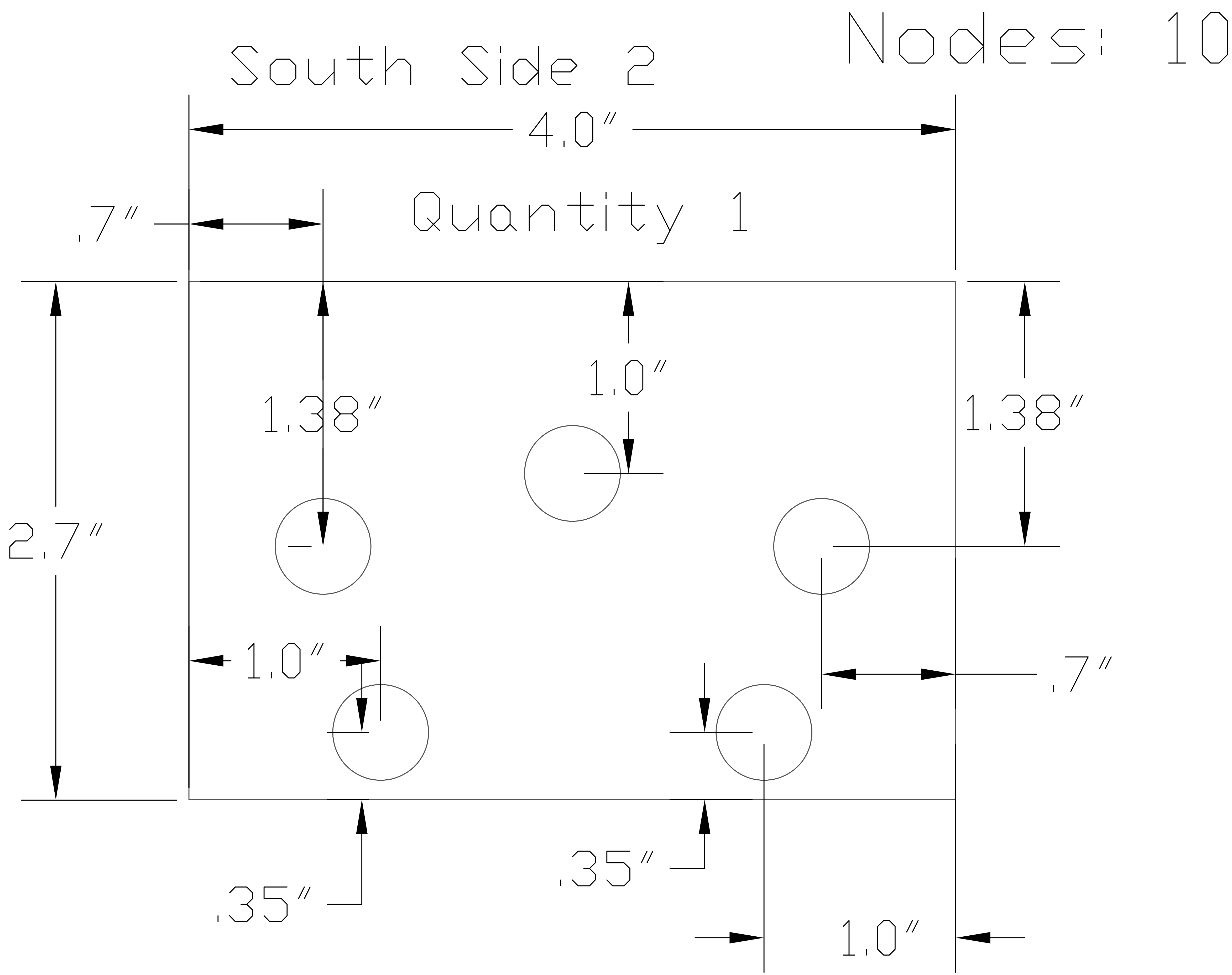
STEEL-BRIDGE
CONNECTION-SCHEMATICS



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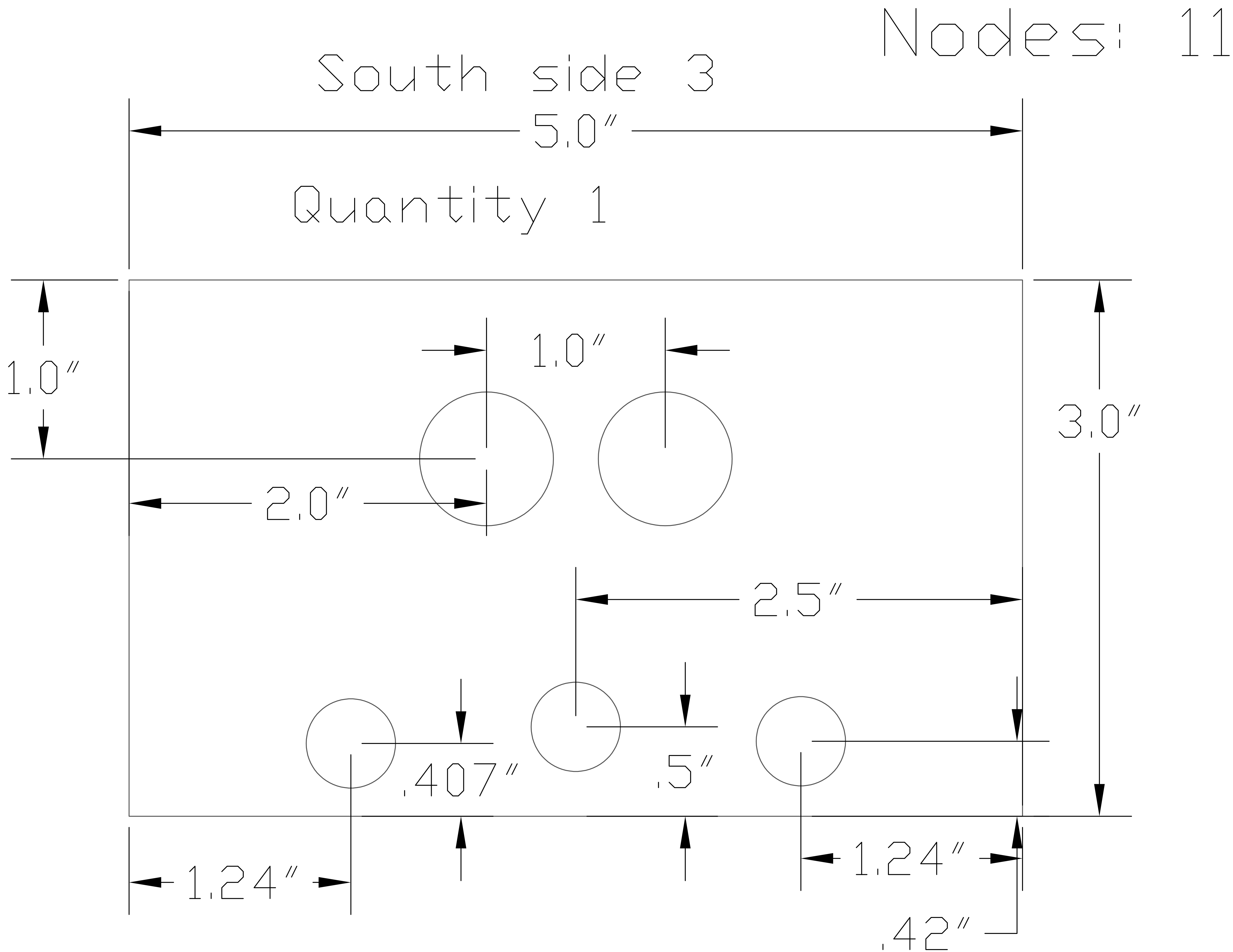
STEEL-BRIDGE
CONNECTION-SCHEMATICS



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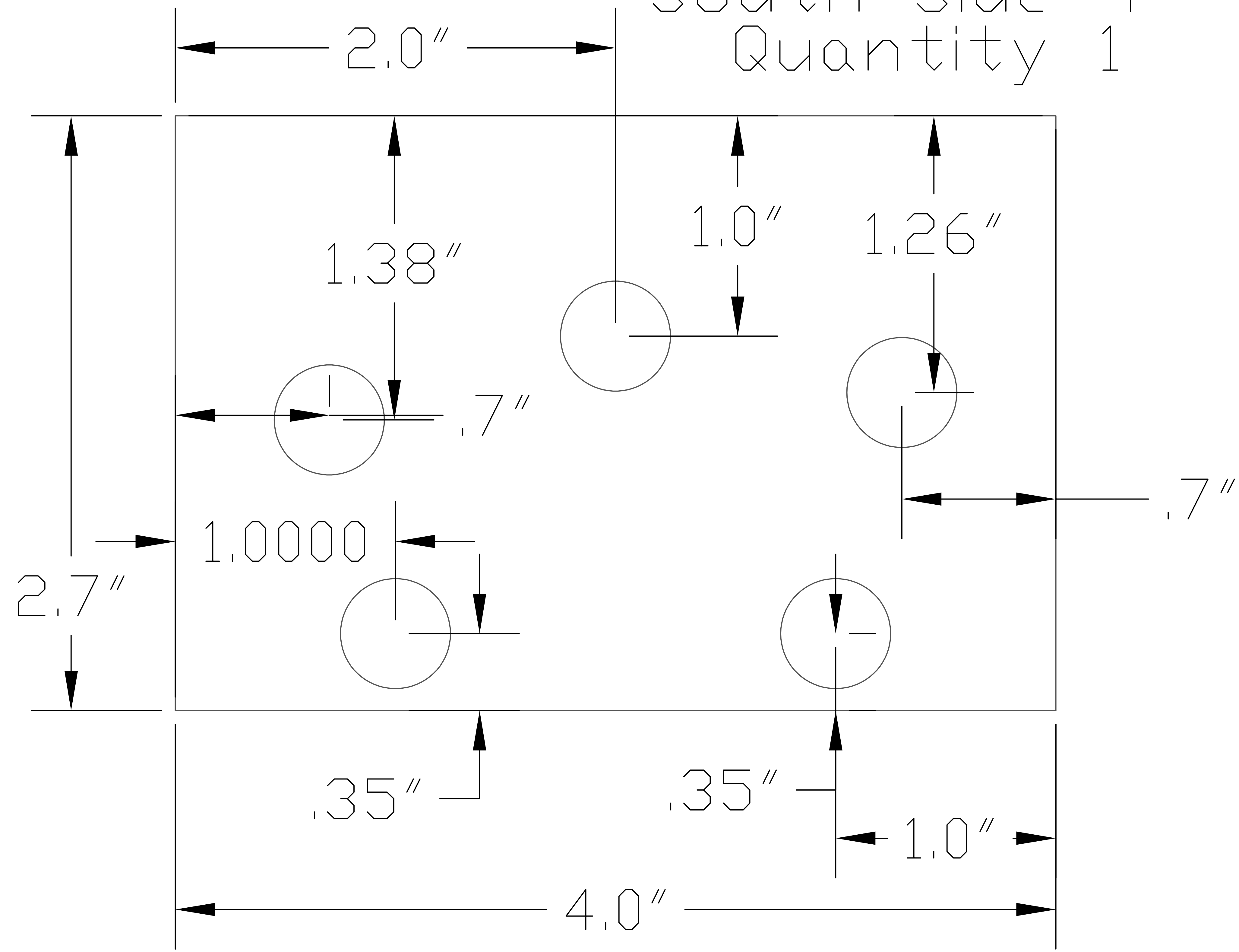
SCALE: 1:2

STEEL-BRIDGE
CONNECTION-SCHEMATICS

Nodes: 14

South Side 4
Quantity 1



~SHEET~ 1 OF 1

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REVISIONS | NO. | DATE | COMMENTS

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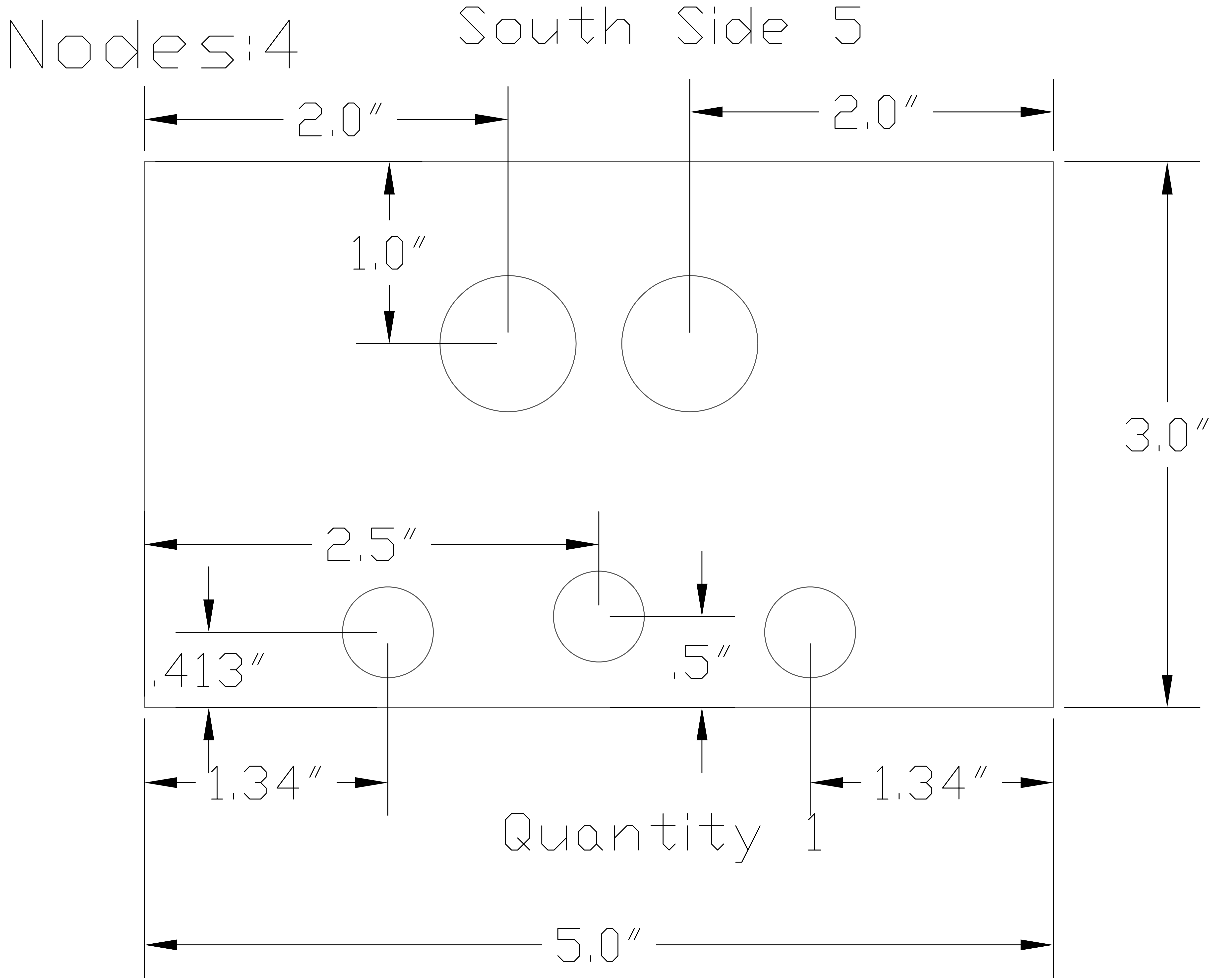
SCALE: 1:2

STEEL-BRIDGE
CONNECTION-SCHEMATICS



~SHEET~
1 OF 1

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REVISIONS NO.	DATE	COMMENTS
1	4/19/22	
X	X/XX/XX	
X	X/XX/XX	

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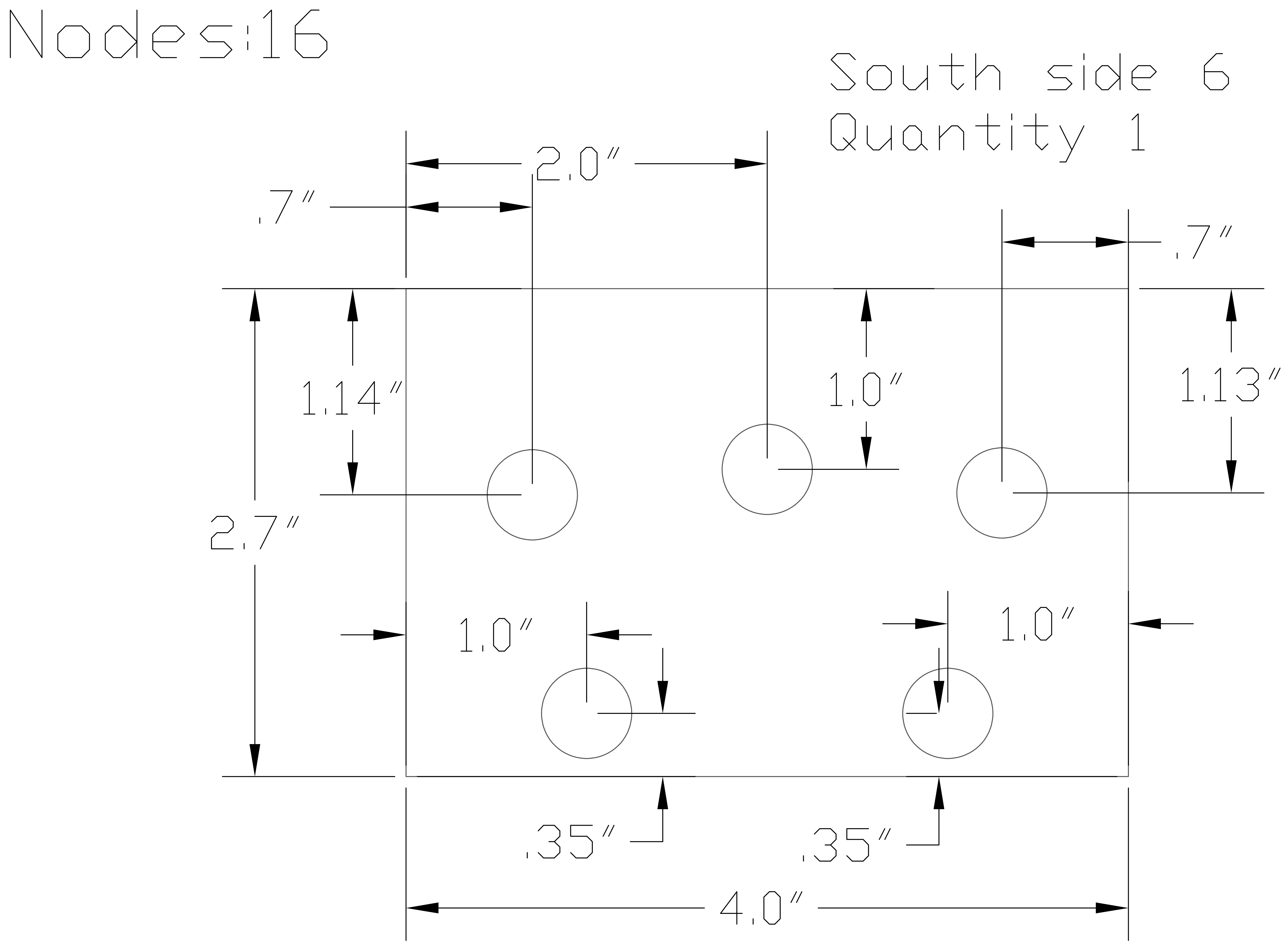
STEEL-BRIDGE
CONNECTION-SCHEMATICS


Nodes:16
South side 6
Quantity 1
2.0"
.7"
.7"
1.14"
1.0"
1.13"
2.7"
1.0"
1.0"
.35"
.35"
4.0"

~SHEET~
1 OF 1
Northern Arizona University
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REVISIONS
NO. DATE COMMENTS
1 4/19/22
X X/XX/XX
X X/XX/XX
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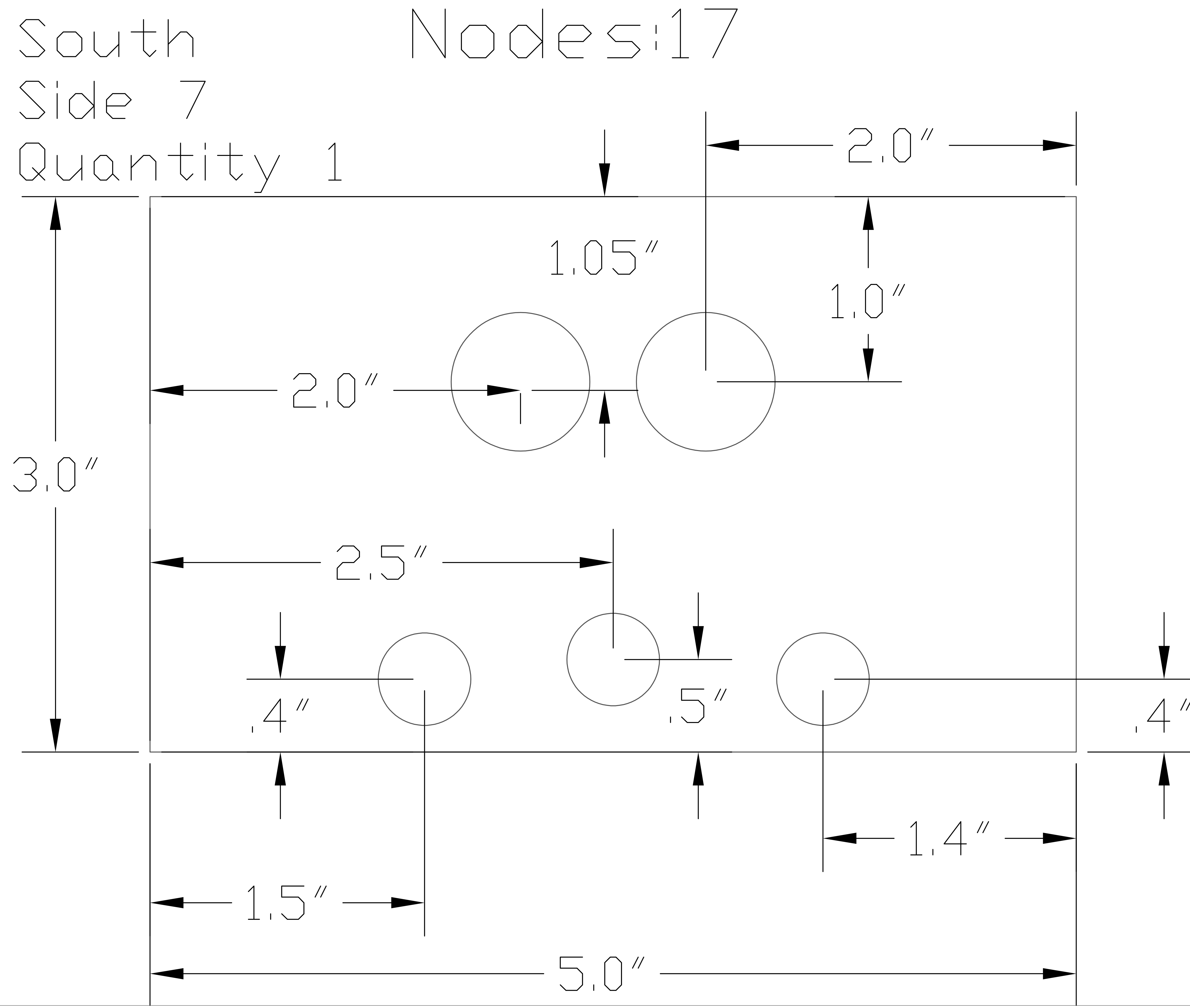

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REVISIONS NO.	DATE	COMMENTS
1	4/19/22	
X	X/XX/XX	
X	X/XX/XX	

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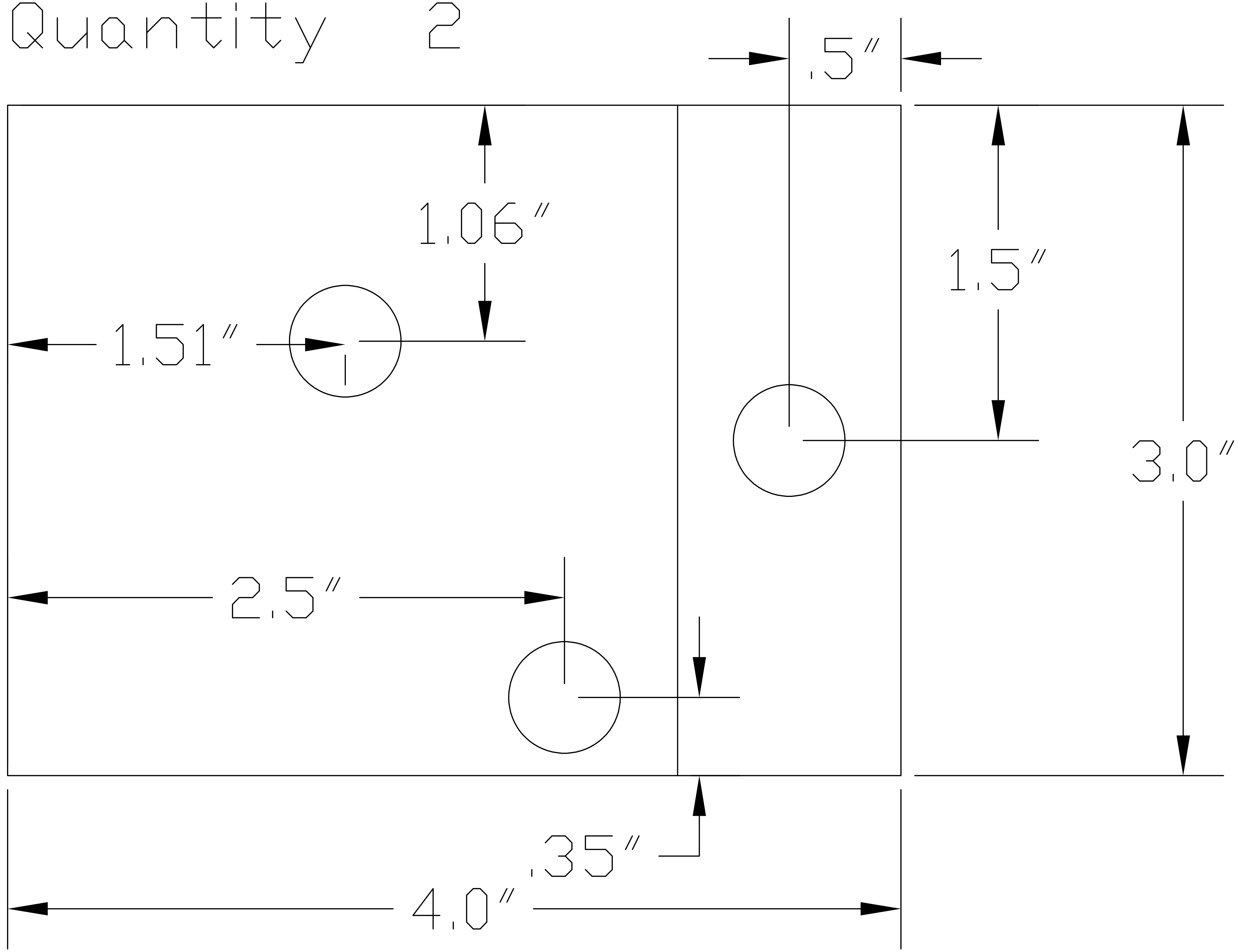
STEEL-BRIDGE
CONNECTION-SCHEMATICS

Nodes:20,42

South side 8
Quantity 2



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1	4/19/22	
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X	X/XX/XX	

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SCALE: 1:2

STEEL-BRIDGE
CONNECTION-SCHEMATICS