TRUSS-TY ENGINEERING

STEEL BRIDGE FINAL PRESENTATION

Alexa Godkin, Sydney Juve, Kyler Wilkens, Lilly Zelenka

CENE 486

May 2, 2025

Project Introduction

Purpose:

- Design and construct a 1:10 scale model of a bridge
- Compete in Student Steel Bridge Competition
- Assembled, loaded and scored in a variety of categories

Figure 1, Student Steel Bridge Competition [1]

Background Research

- Steel Properties and Types
- FHWA Steel Bridge Design Handbook
- SSBC Rules

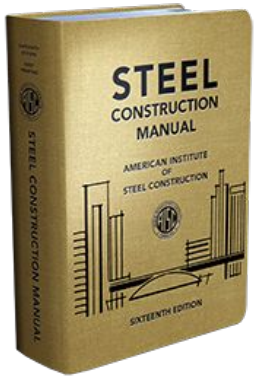


Figure 2, AISC Steel Construction Manual [2]

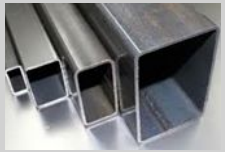
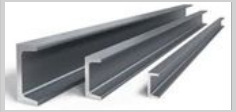
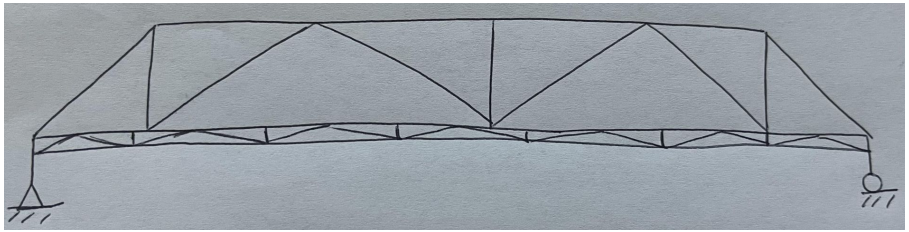
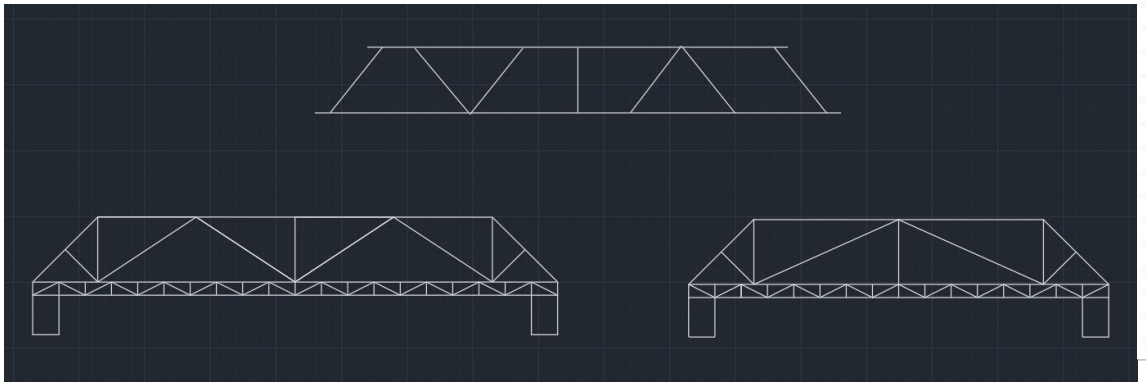
Steel Type	Yield Strength F_y (ksi)	Ultimate Strength F_u (ksi)	Steel Image	Typical Bridge Use
Hollow Structural Sections (HSS)	50	62		Cross bracing, truss members, and secondary members subject to compression
Pipes	35	60		Tension members
Channels	50	65		Stringers
Wide Flange Beams	50	65		Truss Chords

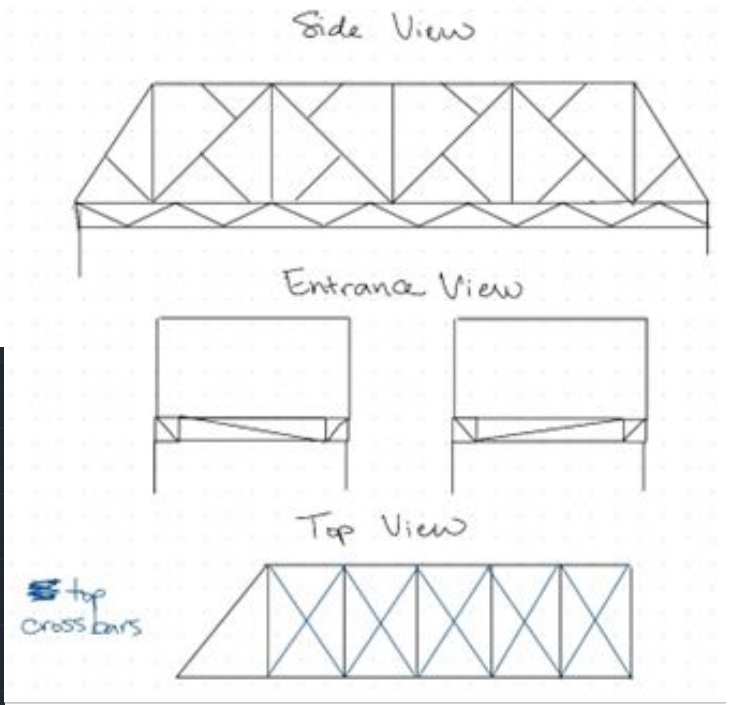
Table 1: Steel shapes and uses [3]

Design

Brainstorming & Preliminary Sketches:

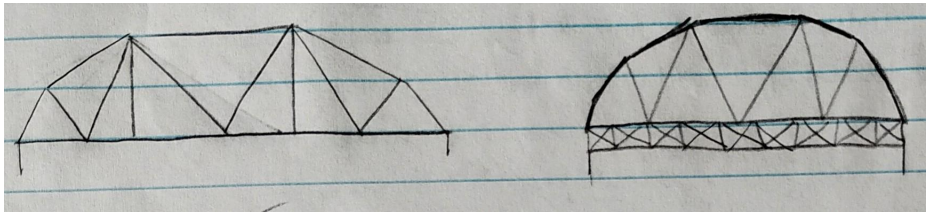


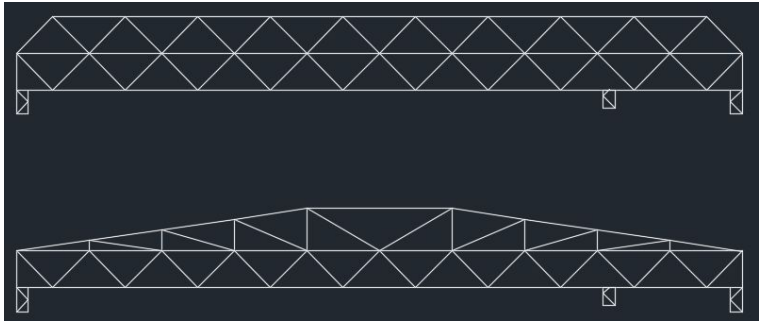


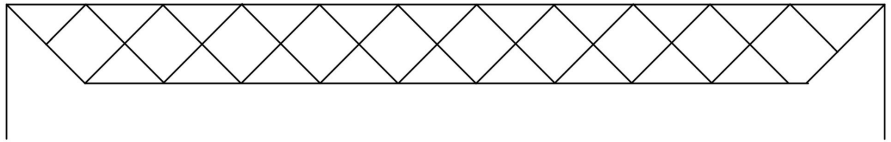


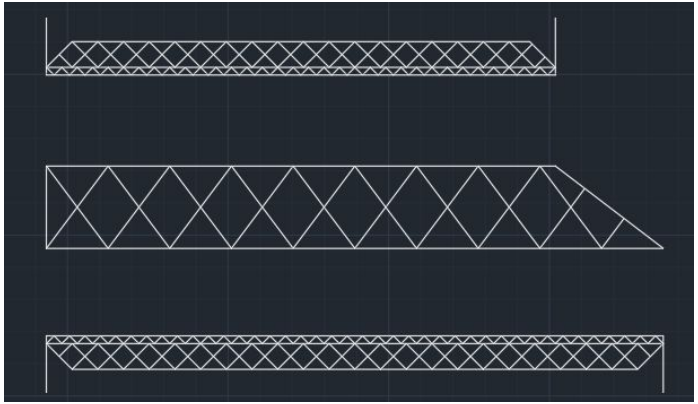
Design (cont.)

Brainstorming & Preliminary Sketches (cont.):



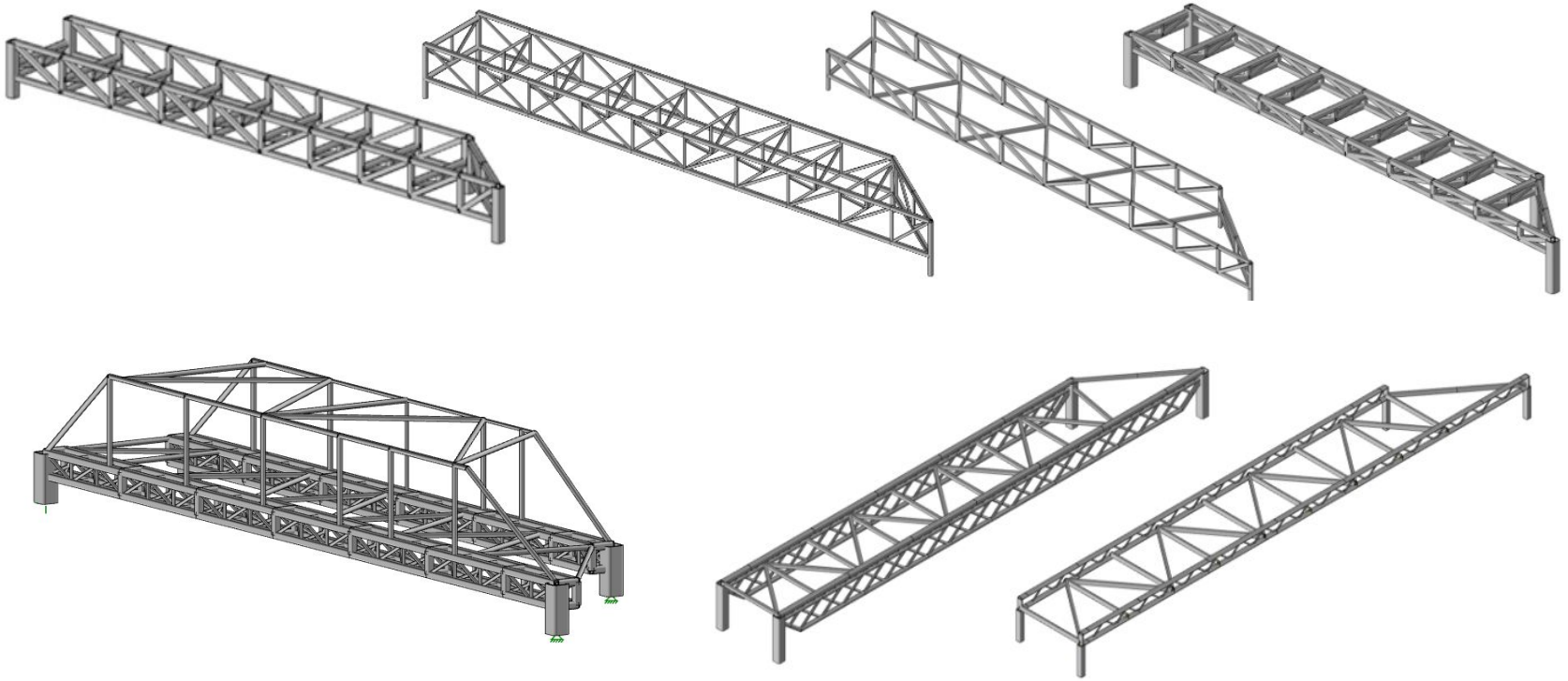






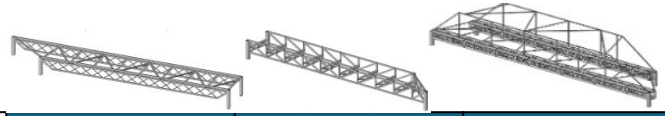
Design (cont.)

RISA-3D Models:

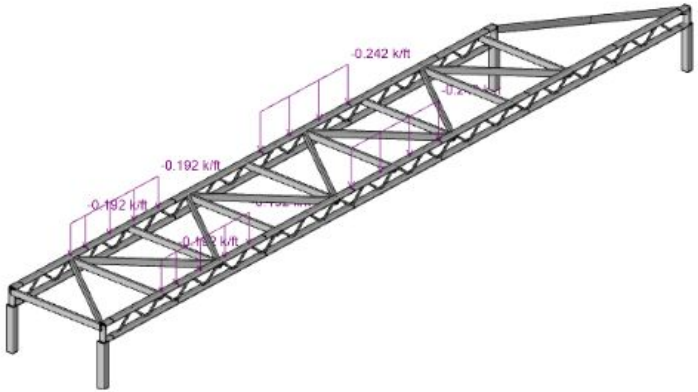


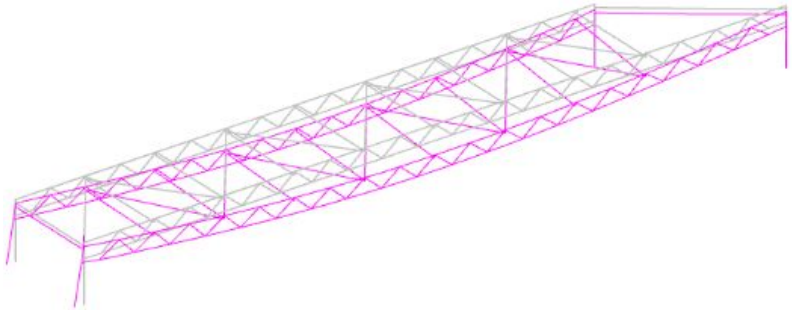
Design (cont.)

RISA-3D Models (cont.):



	Bridge 1	Bridge 2	Bridge 3
Lateral Deflection (in)	0.66	0.27	0.38
Vertical Deflection (in)	0.43	0.42	0.55
Weight (lb)	563	754	689
Number of Pieces	57	91	125

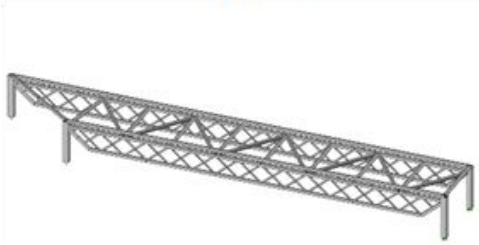
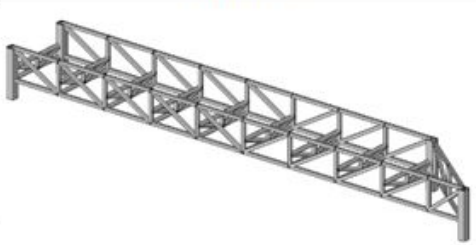




Design (cont.)

Decision Matrix (Round 1):

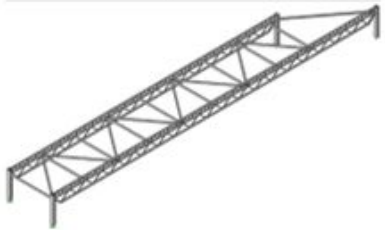
$$Raw\ Score = \frac{Actual\ Value}{Max\ Value\ in\ Category}$$

Bridge Decision Matrix									
	Option 1			Option 2			Option 3		
									
	Actual	Raw Score	Weighted	Actual	Raw Score	Weighted	Actual	Raw Score	Weighted
Lateral deflection (20%)	0.66 in.	1	0.2	0.27 in.	0.4	0.08	0.38 in.	0.6	0.12
Vertical deflection (15%)	0.43 in.	0.8	0.12	0.42 in.	0.8	0.12	0.55 in.	1	0.15
Weight (30%)	563 lb	0.7	0.21	754 lb	1	0.3	689 lb	0.9	0.27
Constructability (30%)	57 Pieces	0.5	0.15	91 Pieces	0.7	0.21	125 Pieces	1	0.3
Aesthetics (5%)	2	0.6	0.03	1	0.3	0.015	3	1	0.05
Total			**0.71**			**0.725**			**0.89**

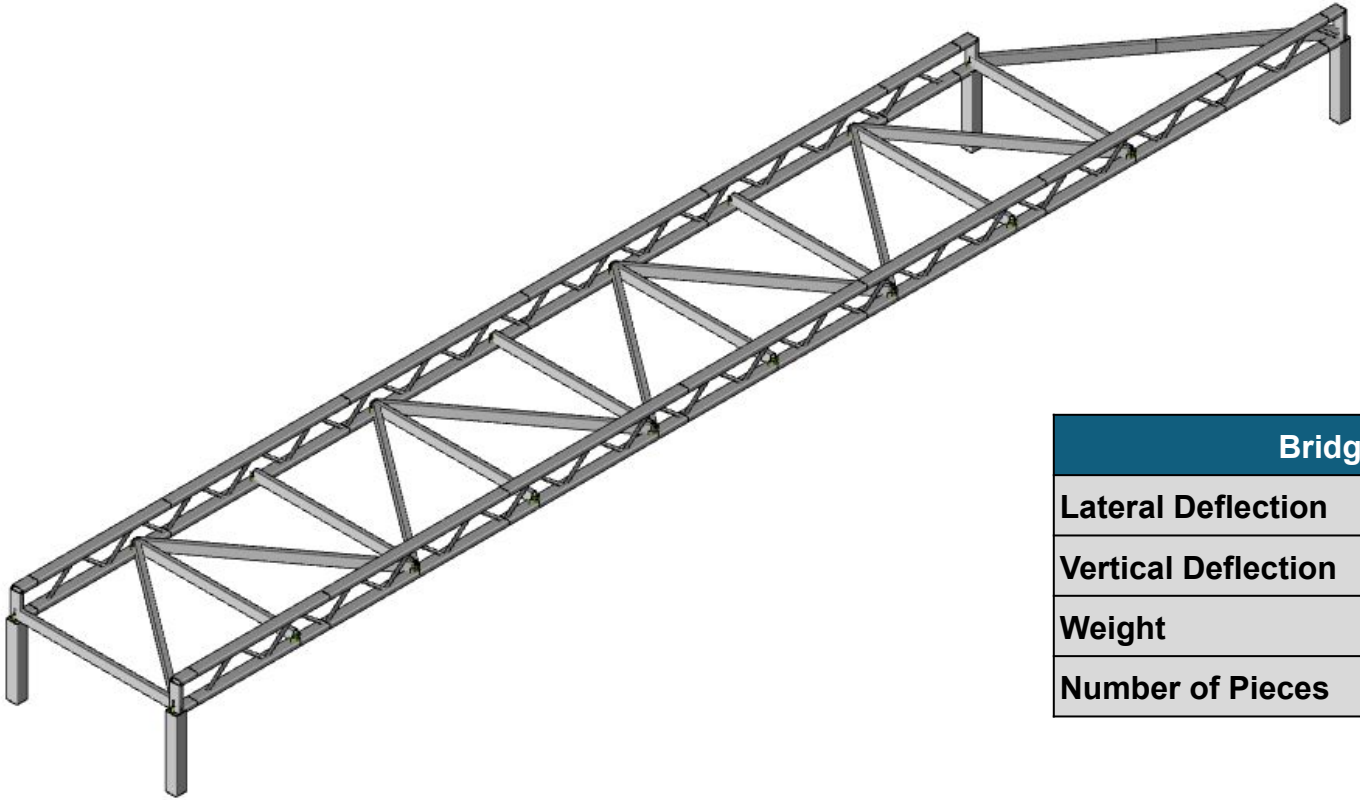
Design (cont.)

Decision Matrix (Round 2):

$$Raw\ Score = \frac{Actual\ Value}{Max\ Value\ in\ Category}$$

	Bridge Decision Matrix (Round 2)					
	Option 1			Option 2		
						
	Actual	Raw Score	Weighted	Actual	Raw Score	Weighted
Lateral deflection (20%)	0.59 in.	1.0	0.20	0.40 in.	0.7	0.13
Vertical deflection (15%)	1.36 in.	1.0	0.15	0.43 in.	0.3	0.05
Weight (30%)	287 lb	0.8	0.23	372 lb	1.0	0.30
Constructability (30%)	49 Pieces	0.5	0.16	90 Pieces	1.0	0.30
Aesthetics (5%)	1	1.0	0.05	1	1.0	0.05
Total			**0.79**			**0.83**

Final Bridge Design



Bridge 1	
Lateral Deflection	0.59 in
Vertical Deflection	1.89 in
Weight	291 lb
Number of Pieces	36

Connection Design - Constraints

SSBC Connection Rules:

- Members Touching Require a Connection
- 3.5’ x 6” x 4” Box for Welded Pieces
- Minimum and Maximum Faying Surfaces
- Interlocking Connections Prohibited
- Stringer Template Interference
- Material Availability

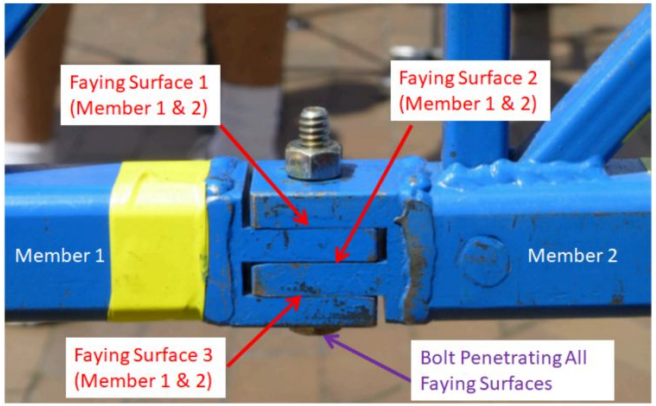


Figure 4, Prohibited Connection [3]

Figure 3, Legal Connection [4]

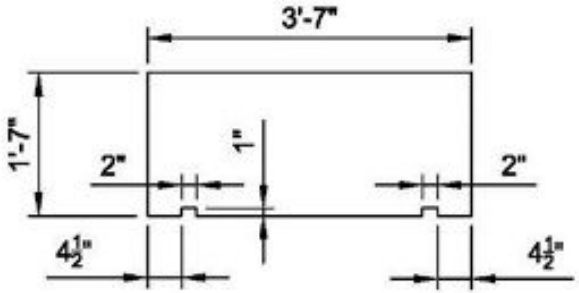


Figure 5, Stringer Template [5]

Connection Analysis - Connection Calculations

Procedure:

- Sketch connection ideas
- Load RISA-3D bridge model
- Worst case shear, moment, and axial loads
- Use AISC Steel Construction Manual for weld, bolt, and plate sizes

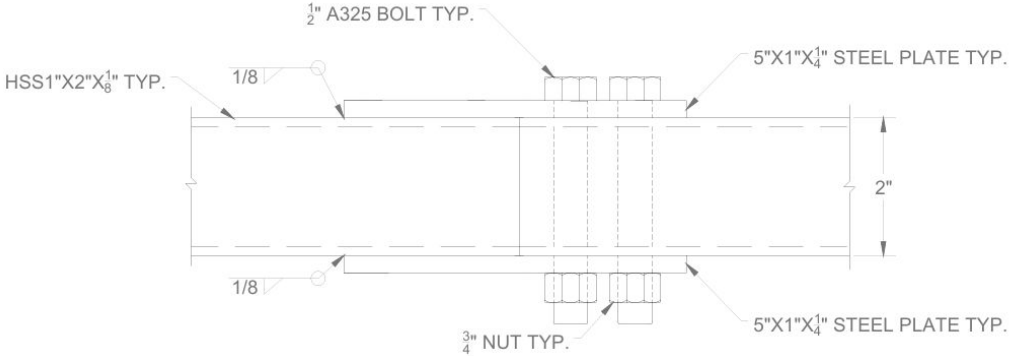


Figure 6, AutoCAD Drawn Connection After Analysis

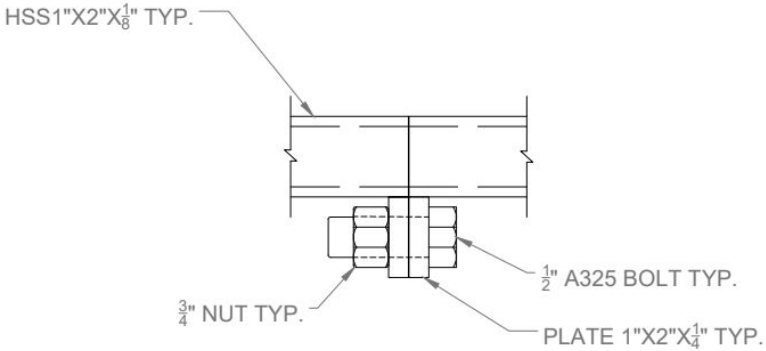


Figure 7, AutoCAD Drawn Connection After Analysis

Connection Design - Connection Types

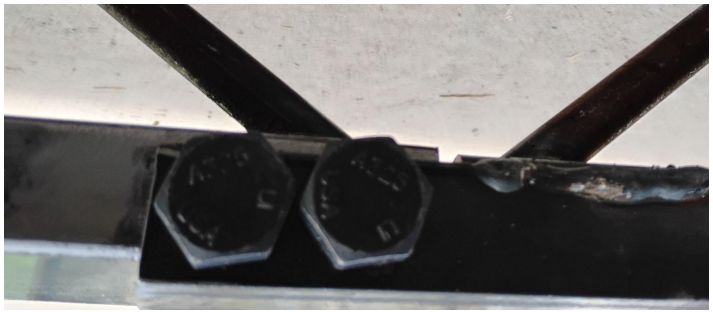


Figure 8, Connection 1

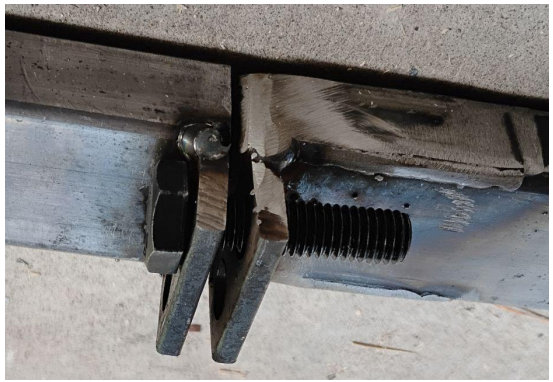


Figure 9, Connection 2

Figure 10, Connection 3

Figure 11, Connection 4

Connection Analysis - Welds

Weld Calculations:

- Example Connection 2 Calc.
- Capacity : Demand = 13.9
- AISC Manual for Steel Construction
  - Strength of Weld
  - Strength of Base Material

Tabs for Connection 2

Strength of Weld Calc

Demand

Demand	=	1.20	kip	
D	=	2.00	/16"	from table J2.4 min=2/16"
l	=	6.00	"	
Fexx	=	70.00	ksi	
Φ	=	0.75		
Available strength of Weld	=	16.71	kip	

Strength of Base Material Calc

Fbm	=	35.00	ksi
Abm	=	0.50	in^2
Rn	=	17.50	kip

Capacity

Available Strength of Connection = 16.71 kip

GOOD

Use: 1/8" weld all around where specified

Connection Analysis - Bolts

Bolt Calculations:

- Example Connection 2 Calc.
- Capacity : Demand = 2.5
- AISC Manual for Steel Construction
  - Strength of Bolt
  - Failure Modes

Through-bolting shear check: — AISC Part 7, Page 13

R_u	=	1.20 k	*shear from RISA*
n	=	1.00	*number of bolts*
F_y	=	36.00 ksi	
d	=	0.50 in	*bolt diameter*
t	=	0.13 in	*thickness of HSS*
ϕR_n	=	3.04 k	

Demand

Capacity

Bolt size OK for shear? OK

Bearing Check: — AISC 16.1-109

(combined tension and shear)

F_{nt}	=	90.00 ksi	*tensile strength from J3.2*
F_{nv}	=	60.00 ksi	*shear strength from J3.2*
n_{sp}	=	2.00	*number of shear planes*
f_v	=	3.06 ksi	*required shear strength*
F'_{nt}	=	110.88 ksi	

Is $F'_{nt} < F_{nt}$? No, skip to tension check below

**if bearing applicable* ϕR_n	=	16.33	

Bolt size OK for bearing? OK
**if bearing applicable*

Tension Check: — AISC 16.1-108

R_u	=	1.20 k	*tension from RISA*
F_{nt}	=	90.00 ksi	*tensile strength from J3.2*
A_b	=	0.20 in^2	
ϕR_n	=	13.25	

Bolt size OK for tension? OK

Use: (1) 1/2" A325 bolt

Connection Analysis - Base Material

Base Material Calculations:

- Tension Member Failure Modes
  - Gross Section Yielding (GSY)
  - Net Section Rupture (NSR)
  - Block Shear
- ¼” Thick Plating
- Capacity : Demand = 3.4
- AISC Manual for Steel Construction

	Demand	=	1.20	k
GSY				
	ϕ	=	0.90	
	Ag	=	0.25	in^2
	Fy	=	36.00	ksi
	ϕRn	=	8.10	k
NSR				
	ϕ	=	0.75	
	Ae	=	0.09	in^2
	Fu	=	58.00	ksi
	ϕRn	=	4.08	k
Block Shear				
	ϕ	=	0.75	
	Fu	=	58.00	ksi
	Fy	=	36.00	ksi
	U_{BS}	=	1.00	
	A_{nt}	=	0.08	in^2
	A_{nv}	=	0.20	in^2
	A_{gv}	=	0.44	in^2
	Rn = min	=	11.60	k
		=	13.98	k
	ϕRn	=	8.70	k

Demand

Capacity

Connection Analysis - Summary Table

Welded Connections:

Weld "Type"	Limit States Checked	Controlling D/C Ratio
Truss Web Members to Stringers	- Strength of Fillet Weld - Base Material Yielding - Base Material Rupture	.275 (weld)
Cross-bracing Tabs to Bottom Stringer		.034 (weld)
Vertical Part of Footing to Horizontal Part of Footing		.178 (base material)

Bolted Connections:

Connection	Limit States Checked		Controlling D/C Ratio
	Bolt	Base Material	
1	- Shear - Tension - Bearing	- Yielding - Rupture - Block Shear	.974 (bolt shear)
2			. 395 (bolt shear)
3			.016 (bolt shear)
4			.016 (bolt shear)

Shop Drawings

List of Sheets:

- Schedules and Notes
- Plan and Profile Views
- Welded Piece Details
- Connection Locations
- Connection Details

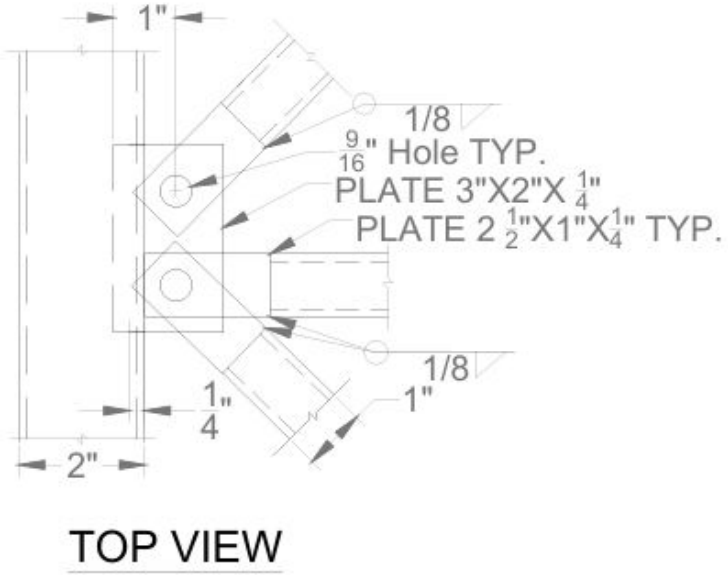


Figure 13, Shop Drawing Connection Detail

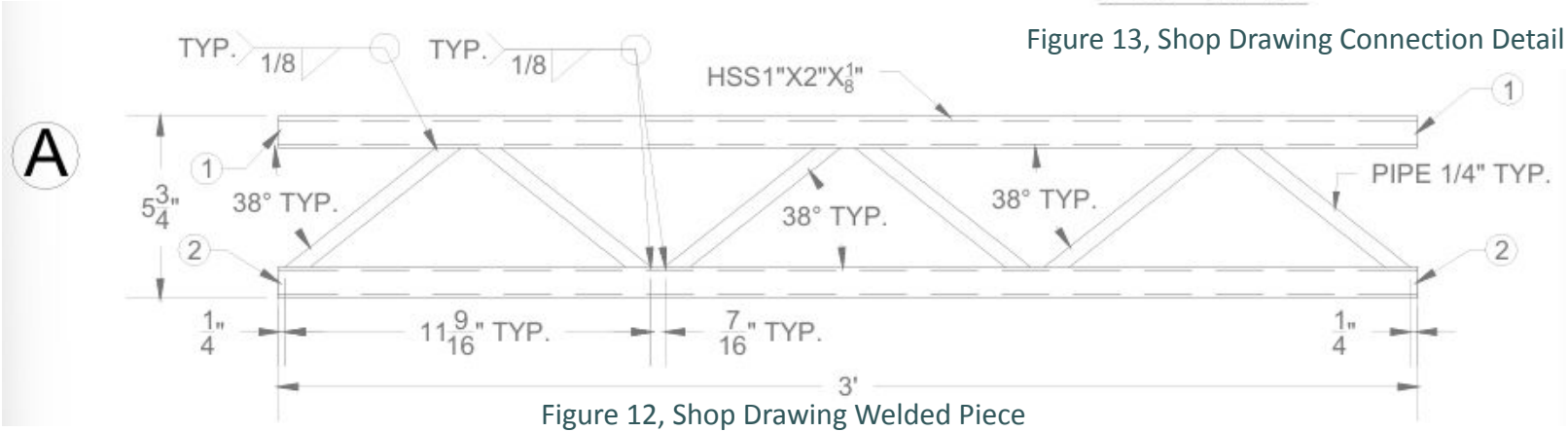


Figure 12, Shop Drawing Welded Piece

CUT STEEL MEMBERS SCHEDULE

PIPE $\frac{1}{4}$"	QUANTITY	X65 @ 38"							
	LENGTH	0'-6 1/16"							
HSS 1"X2"X$\frac{1}{8}$"	QUANTITY	X25	X4	X2	X2	X8	x4	X8	X2
	LENGTH	3'-0"	2'-3"	1'-3 3/4"	0'-9 3/4"	0'-4 1/4"	0'-3 3/4"	1'-11 3/4"	2'-0"
HSS $2\frac{1}{2}$"X$2\frac{1}{2}$"X$\frac{1}{8}$"	QUANTITY	X4							
	LENGTH	1'-1 3/4"							
$\frac{1}{4}$" PLATE	QUANTITY	X32	X30	X6	X11	X32	X4	X4	
	LENGTH	5"X1"	1"X2"	3"X2"	$1\frac{1}{2}$" X 2"	$2\frac{1}{2}$" X 1"	$2\frac{1}{2}$" X $2\frac{1}{2}$"	3" X 3"	

WELDED PIECE SCHEDULE

A	X 9
B	X 2
C	X 1
D	X 1
E	X 4

LATERAL BRACING SCHEDULE

HSS 1"X2"X$\frac{1}{8}$"X1' 11$\frac{3}{4}$"	X 8
HSS 1"X2"X$\frac{1}{8}$"X3'	X 7
HSS 1"X2"X$\frac{1}{8}$"X2'	X 2

LEGEND

HIDDEN LINE

SECTION CUT NUMBER

SECTION CUT PAGE

TYPICAL CONNECTION

CONNECTION CALLOUT

TYPICAL TYP.

FILLET WELD CALLOUT

CONNECTION PLATING SCHEDULE

PLATE LENGTH (IN.)	2	2	2 1/2	3	5
PLATE WIDTH (IN.)	1	1 1/2	1	2	1
CONNECTION #					
1					x2
2	x2				
3		X1	VARIES*		
4			X3	X1	

* MAY NEED X1 OR X2 PLATES. SEE PAGE 5 FOR CLARIFICATION

CONNECTION SCHEDULE

CONNECTION #	# OF SIMILAR SECTIONS
1	X16
2	X15
3	X11
4	X6

GENERAL STRUCTURAL NOTES

-TOLERANCES AT CONNECTIONS SHOULD BE WITHIN $\frac{1}{16}$" OF SPECIFIED DIMENSIONS
-ALL WELDS ARE $\frac{1}{8}$"
-ALL BOLTS ARE $\frac{1}{2}$"

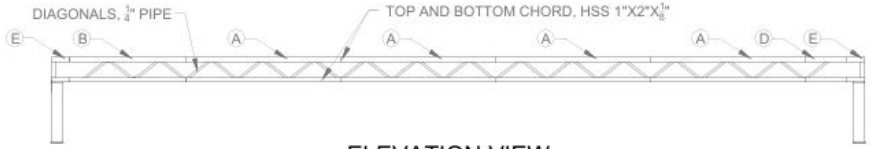
SCALE: N/A
REVISION NO. 5
PAGE: 1 of 8
DRAWN BY: AG
CHECKED BY: SJ,KW,LZ
DATE: JANUARY 2025

2025 NAU STEEL BRIDGE

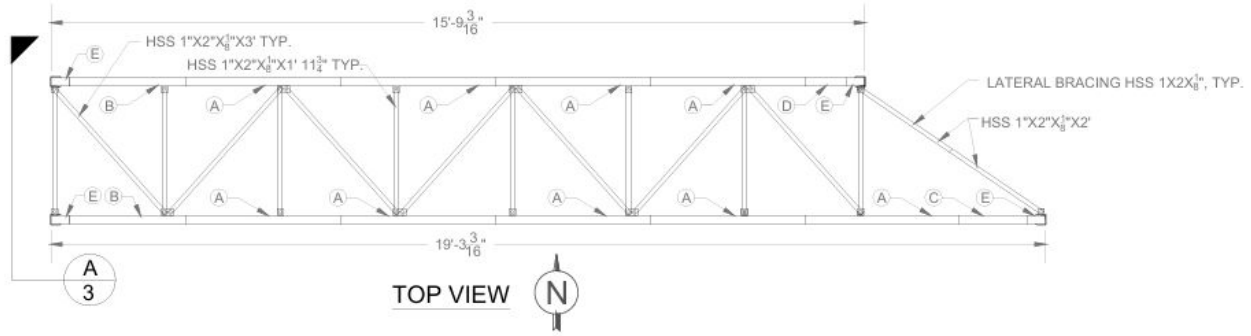
STEEL MEMBER SCHEDULE

TRUSS-TY ENGINEERING

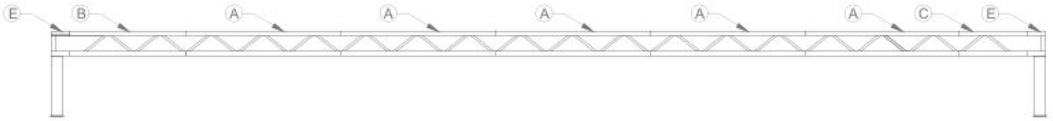
NOTES:
REFER TO SHEETS 3 THRU 4
FOR PART DETAILS



ELEVATION VIEW
(LOOKING SOUTH)



TOP VIEW



ELEVATION VIEW
(LOOKING NORTH)

2025 NAU STEEL BRIDGE

PLAN & PROFILE VIEWS
CONNECTION LOCATIONS

DRAWN BY: AG
CHECKED BY: SJ,KW,LZ
DATE: JANUARY 2025
SCALE: 1/2"=1'
REVISION NO. 5
PAGE: 2 of 8

TRUSS-TY ENGINEERING

Coordination - Page Steel

- Order Steel Members
  - A36 ¼” Plating - 6 ft^2
  - A500 HSS 1x2x1/8 - 110 ft
  - A500 ¼” HSS Pipe - 35 ft
  - A500 HSS 2.5x2.5x1/8 - 5 ft

Figure 14, Steel Plating [6]

Figure 15, HSS Piping [7]

Figure 17, Page Steel Logo [9]

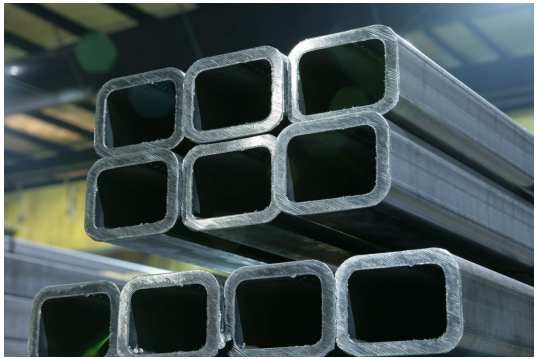


Figure 16, HSS Tubing [8]

Coordination - Flagstaff High School

- Provide Completed Shop Drawings
- Deliver Steel
- Pick up Welded Pieces of Bridge

Figure 18, Flagstaff High School Logo [10]

Figure 19, Flag High Student Welding the Bridge [11]

Team Fabrication

- Cut off and re-weld Connections 1 and 2
- Use 1” angles in place of tabs for Connection 1
- Drill holes for Connections 3 and 4

Figure 20, Bridge Pieces Partially Assembled

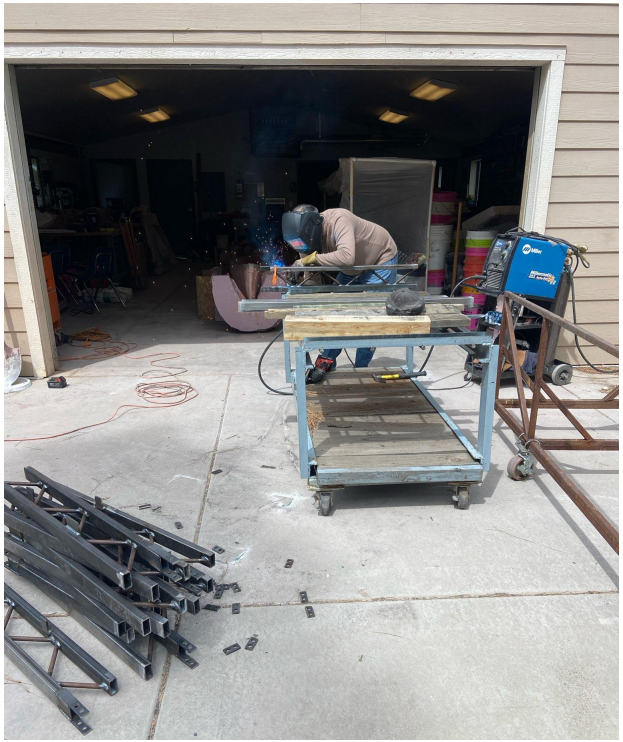


Figure 21, Re-welding Connections

Coordination - Copper State

- Order Nuts and Bolts for Connections
  - ½” Diameter A325 Bolts
    - 3” Length - 32x
    - 2” Length - 53x

Figure 22, Example Bolted Connection [12]

Figure 23, A325 Nut and Bolt [13]

Figure 24, Copper State Nut and Bolt Logo [14]

Steel Bridge Competition

- **Display Day:**

Figure 25, Display Day [1]

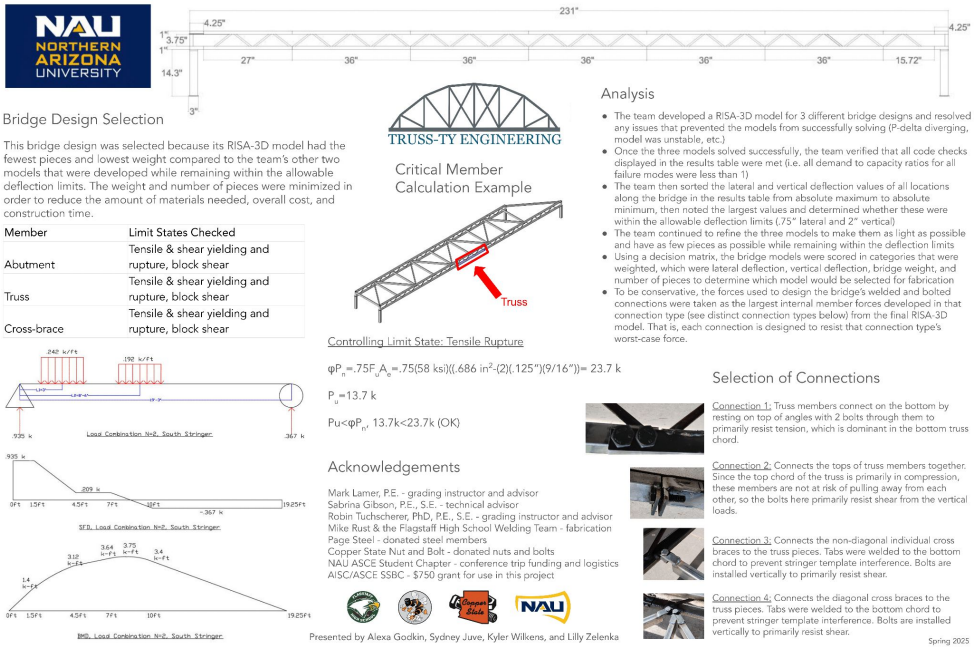


Figure 26, Display Day Poster

Steel Bridge Competition

- **Competition Day:**

Figure 27, Competition Day [1]

Figure 28, Competition Day [1]

Steel Bridge Competition (cont.)

- **Competition Day:**

Figure 29, Team Picture with Loading on Bridge [15]

Category	Results
Construction Time	37 minutes, 8 seconds
Bridge Weight	306 lb.
Lateral Deflection	Not measured, but within 0.5”
Vertical Deflection	3”
Sustained Vertical Load	2025 lb. (81% of 2500 req.)

Impact Analysis

Figure 30, Steel Bridge [16]

	Social	Environmental	Economic
+	Aesthetics Longer Spans	Low carbon footprint Relatively Low Waste Recyclable	Low Labor Costs Short Construction Time
-	Corrosion	Releases VOC's	High Upfront Cost

Lessons Learned

- Overall fabrication process
  - More tolerance in connections
  - Account for inevitable fabrication error
- Quality Control in the fabrication process
  - Subcontractors and team
- Good to be conservative in design but not over-engineer

Figure 31, Incorrectly Fabricated Connection

Figure 32, A325 Nut and Bolt [13]

Figure 33, Pieces with Re-welded Connections

THANK YOU

Figure 34, Team Picture with Loading on Bridge [15]

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