Steel Bridge Final Presentation

CENE 486C
May 1st, 2026

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Project Introduction
Overview & Location

- Design and build a 1:10 scale model of a 240’ pedestrian bridge. Compete in the Intermountain Southwest Student Symposium (ISWS) Steel Bridge Competition
- Bridge will be in the northern region of El Paso, Texas over the Rio Grande

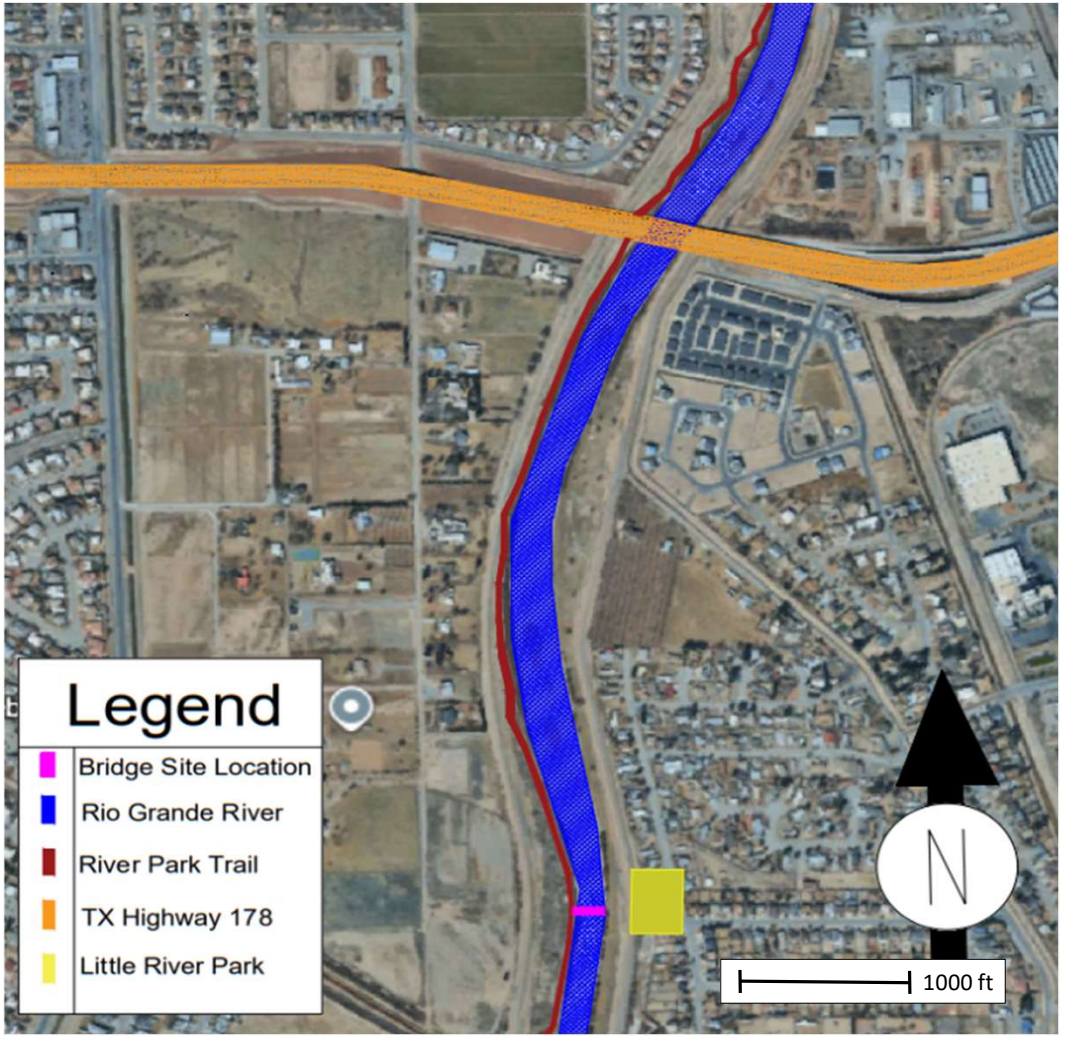

Figure 1: Vicinity Map [1]

Project Introduction
Constraints

- Competition rules dictate that the bridge deck cannot vertically extend past 2'2"
- All members must fit into 3'6" x 4"x 6" box
- 45 minutes maximum for construction time during competition

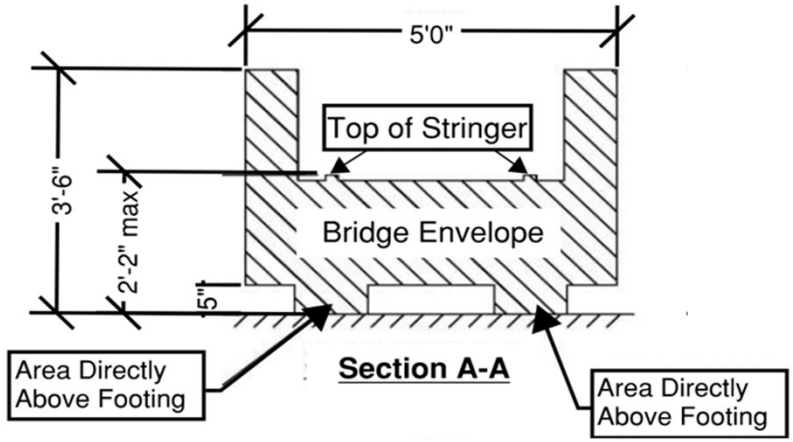

Figure 2: Section A-A Bridge Envelope [2]

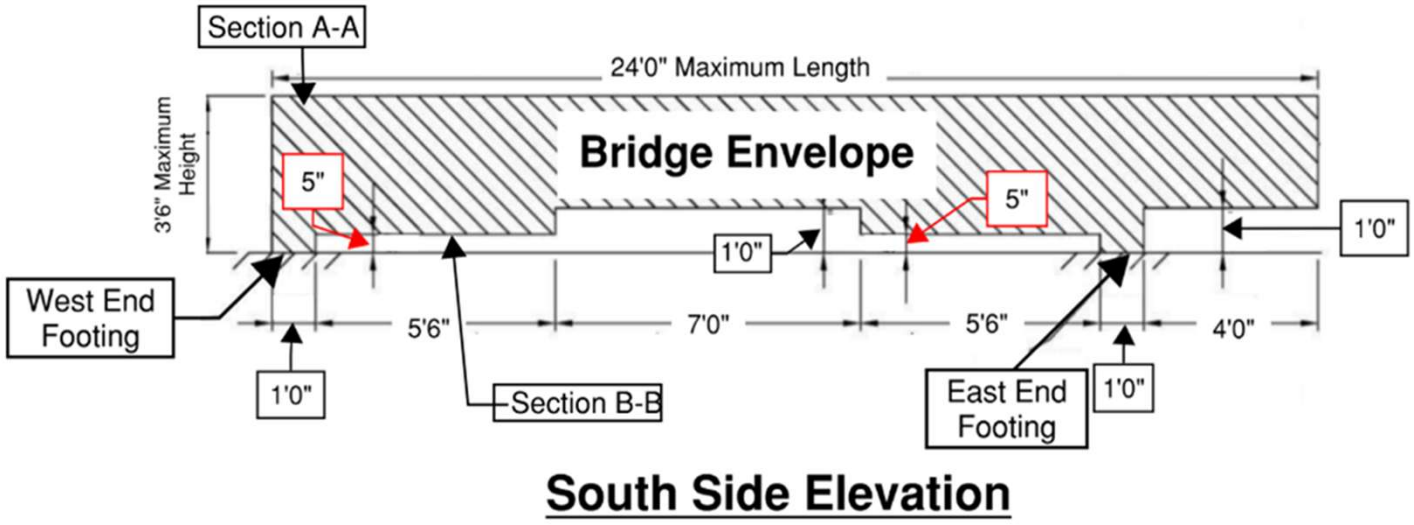

Figure 3: South Side Bridge Envelope [2]

Background Research
Truss Type Research

Figure 4: Underslung Truss Example [3]

- Bridge Type: Underslung Truss
  - Compatible Truss types:

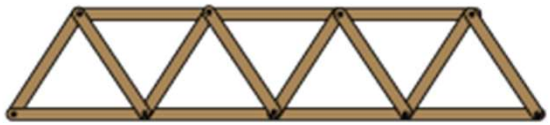

Figure 5: Warren Truss [3]

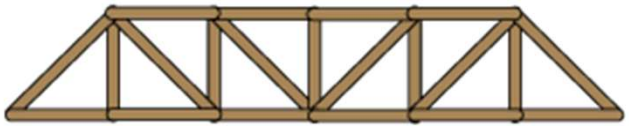

Figure 6: Pratt Truss [3]

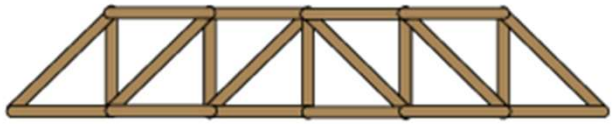

Figure 7: Howe Truss [3]

Background Research
Material & Member Research

- Steel Type:
  - Steel availability, cost, and structural efficiency
  - Carbon Steel A36 and A500
- Member Shapes:
  - Influences the shop drawings, structural efficiency, and weldability
  - Hollow Structural Section (HSS) Rectangular vs Circular

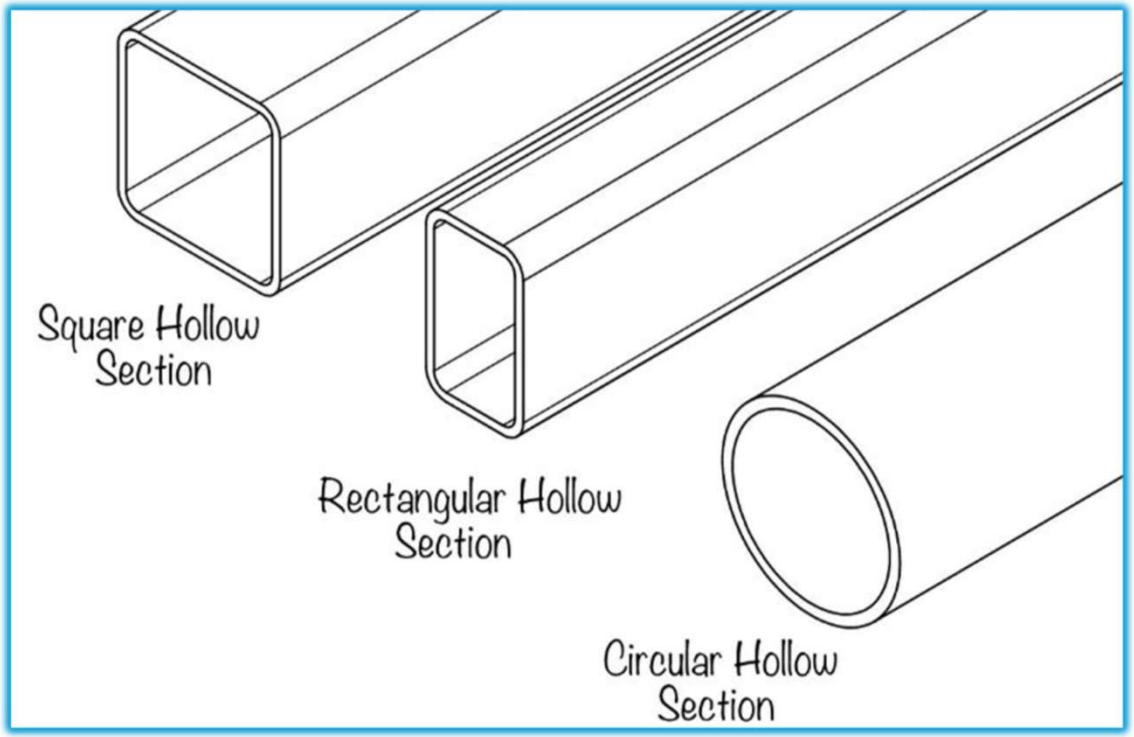

Figure 8: Member Shape Considerations [4]

Background Research
Connection Research

- Research Results:
  - Competition rules limit connection types to welds and bolts
    - Welds must be done outside of competition
    - All bolted connections must be done within the competition's construction time
  - Bolts: Allow larger members while keeping them individual, lower capacity compared to welds
  - Welds: Higher capacity, cuts construction time during competition, affects dimensional constraints

Figure 9: Bolts [5]

Figure 10: Weld [6]

Initial Design

Preliminary Sketches

- Bridge Type: Underslung Truss

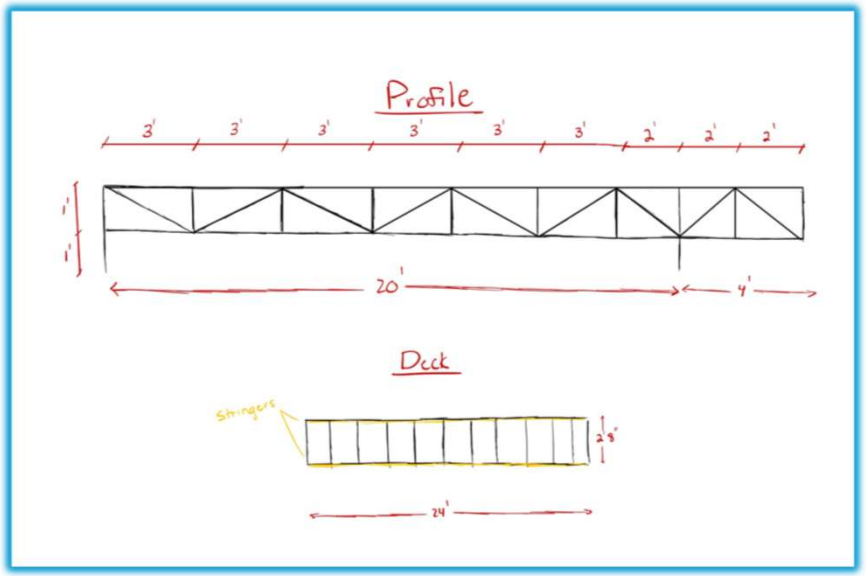

Figure 11: Preliminary Sketch Example #1 [7]

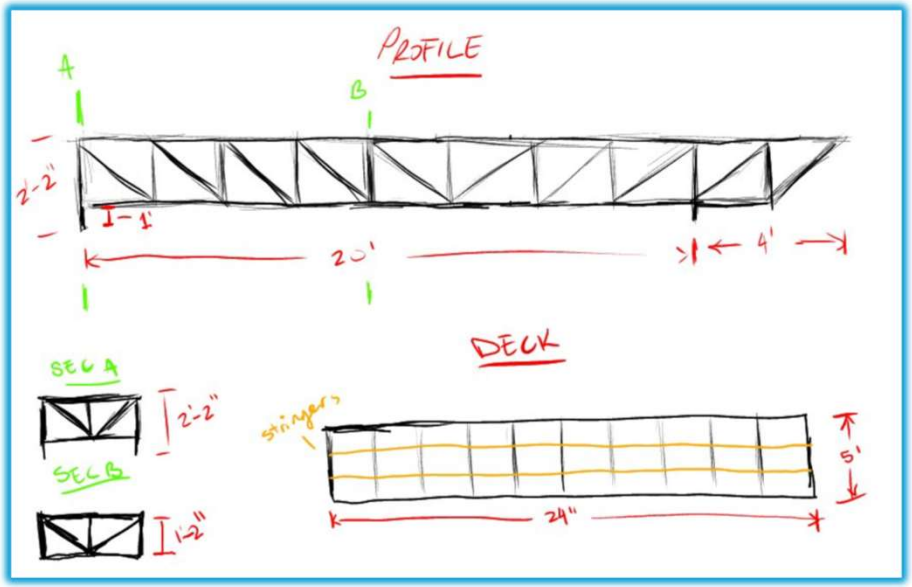

Figure 12: Preliminary Sketch Example #2 [1]

Initial Design

Member & Connection Selection

- Selected Members:
  - Rectangular HSS Members with A500 Steel
- Selected Connections:
  - Welds applied to lateral loads and bolt plates
  - Bolts applied to vertical loads

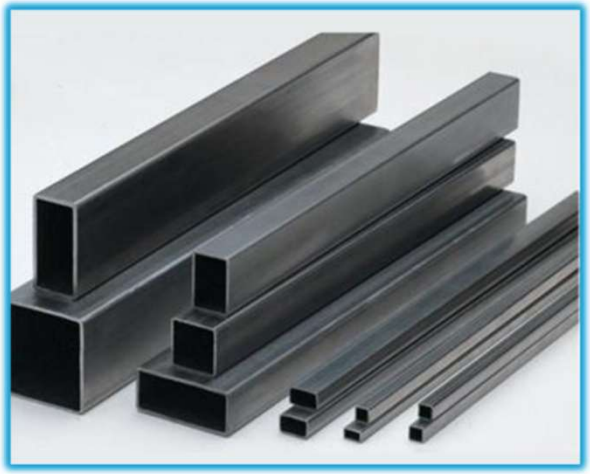

Figure 13: HSS Members [8]

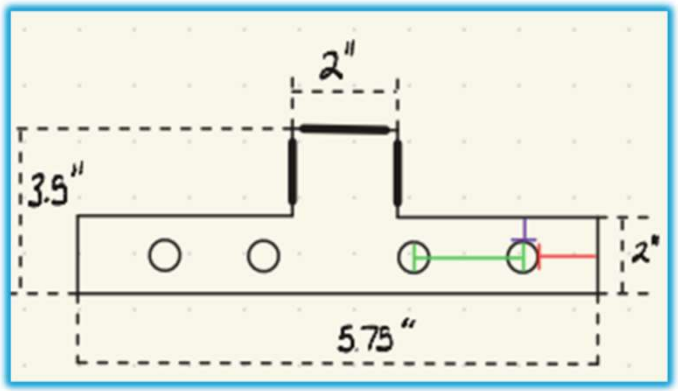

Figure 14: HSS Members [9]

Initial Design

Modeling & Analysis

- Modeling Software: Risa 2D

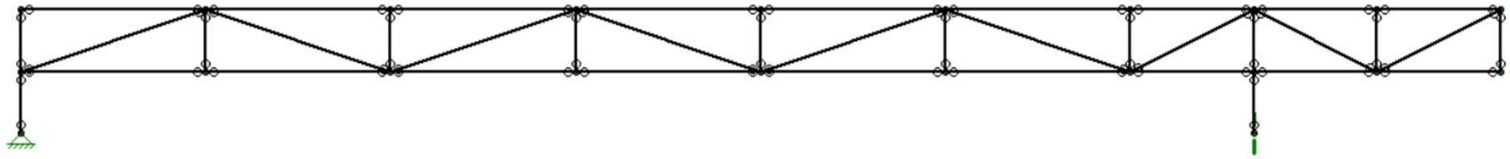

Figure 15: Option 1 – Warren Truss with Vertical Supports [7]

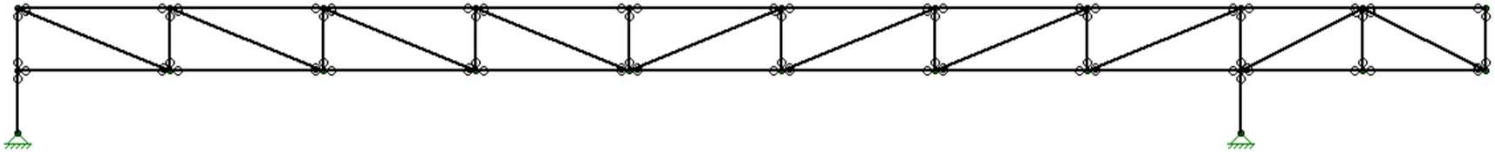

Figure 16: Option 2 - Pratt Truss Version 1 [1]

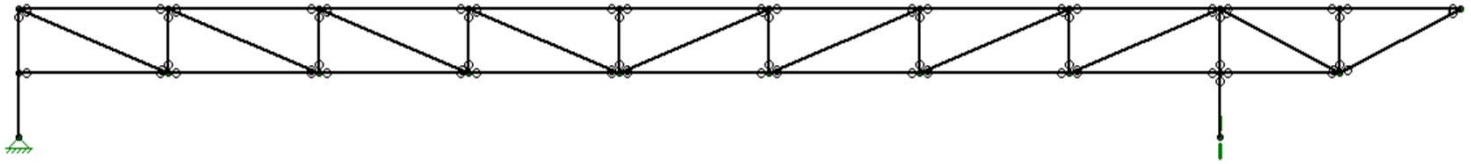

Figure 17: Option 3 - Pratt Truss Version 2 [1]

Initial Design

Design Selection

- Selection Method: Decision matrix

	Weights	Option 1 – Warren Truss	Option 2 – Pratt Truss 1	Option 3 – Pratt Truss 2
Constructability	40%	10	9.6	9.8
Deflection	45%	10	8	9
Aesthetics	15%	9	10	8
Total Weighted Score	100%	9.9	8.9	9.2

Table 2: Decision Matrix

Final Analysis and Design

STAAD Modeling

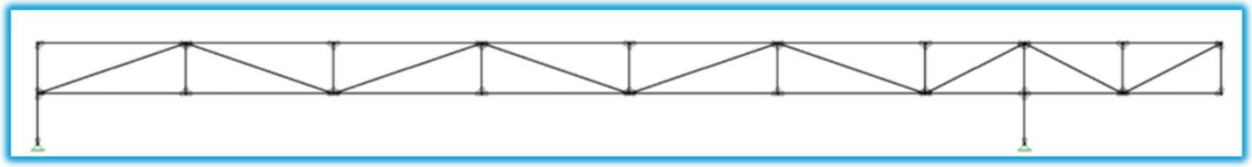

Figure 18: Risa-2D Model [7]

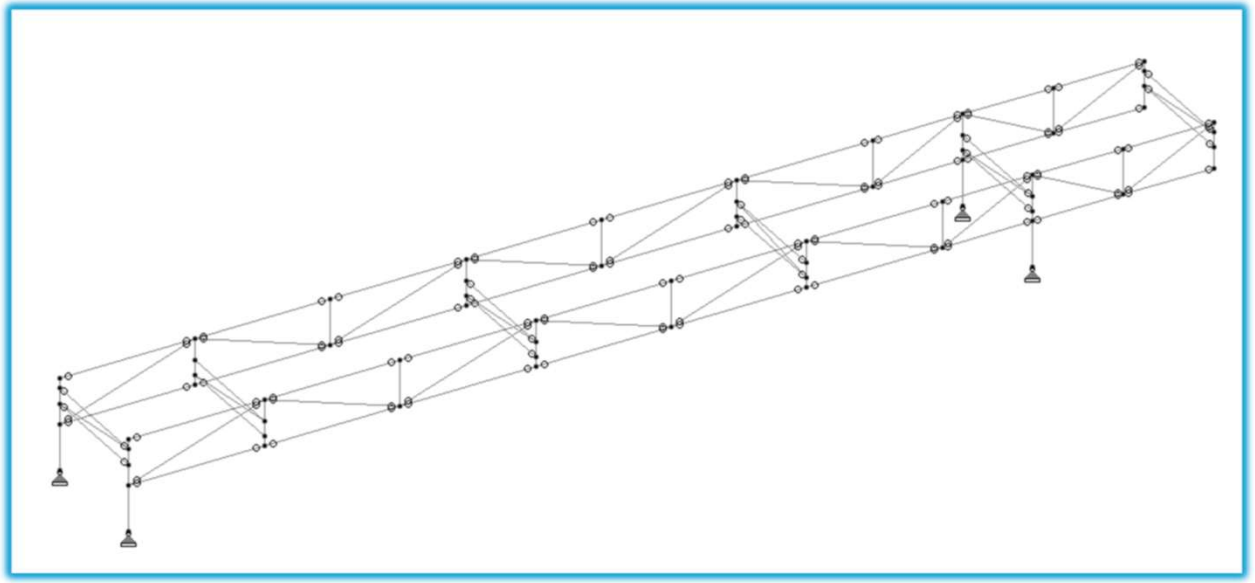

Figure 19: STAAD Model [9]

Final Analysis and Design

Load Cases

- Load Types:
  - Lateral Loads – tests sway
  - Vertical Loads – tests deflection
- 15 total load combinations were needed

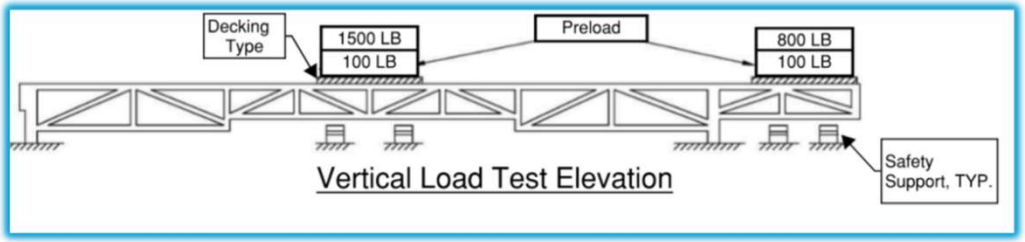

Figure 20: Vertical Load Test [2]

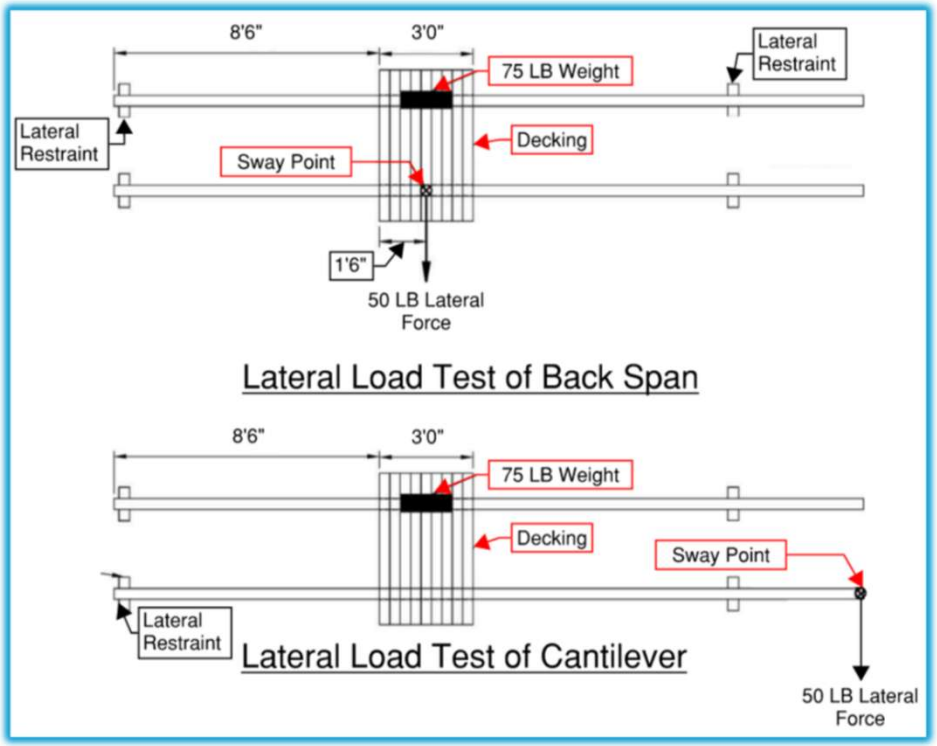

Figure 21: Lateral Load Test [2]

Final Analysis and Design

Lateral Bracing

- STAAD Analysis Results
  - Instability issues
- Refined lateral bracing design

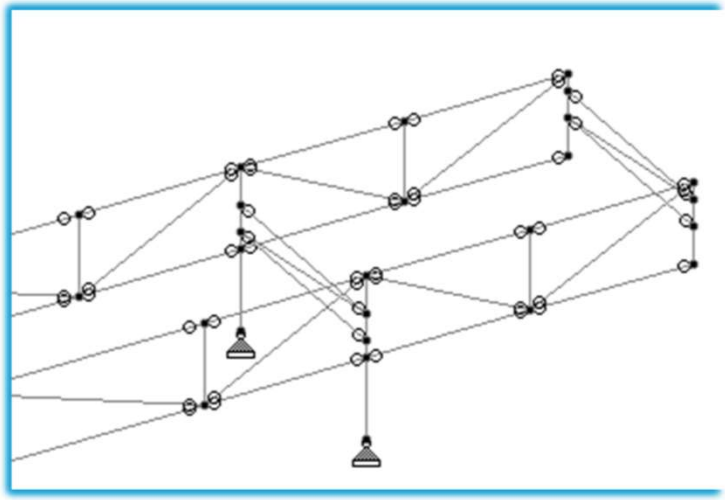

Figure 22: Old Lateral Bracing [9]

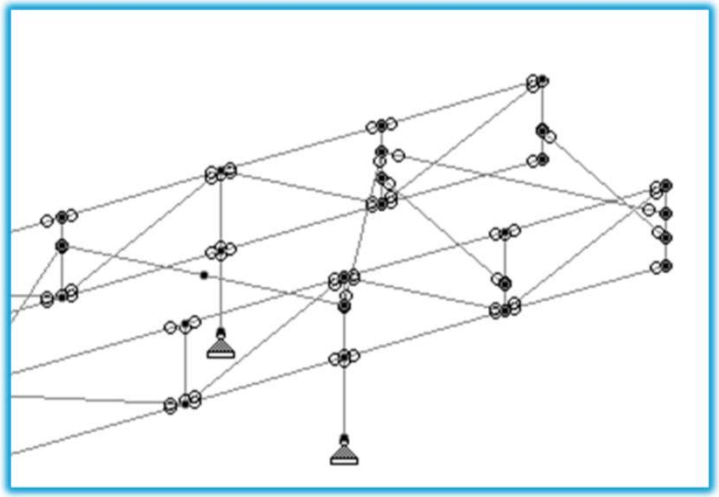

Figure 23: New Lateral Bracing [9]

Final Analysis and Design

Final Decision Matrix

- Review Design Selection

	Weights	Option 1 – Warren Truss		Option 2 – Pratt Truss	
		Actual Number	Score	Actual Number	Score
Constructability	45%	61	10	65	9
Vertical Deflection	30%	0.389 in	9.5	0.345 in	10
Lateral Deflection	20%	0.078 in	10	0.117 in	9.5
Aesthetics	5%	-	9	-	10
Total Weighted Score	100%	-	9.80	-	9.45

Table 3: Decision Matrix

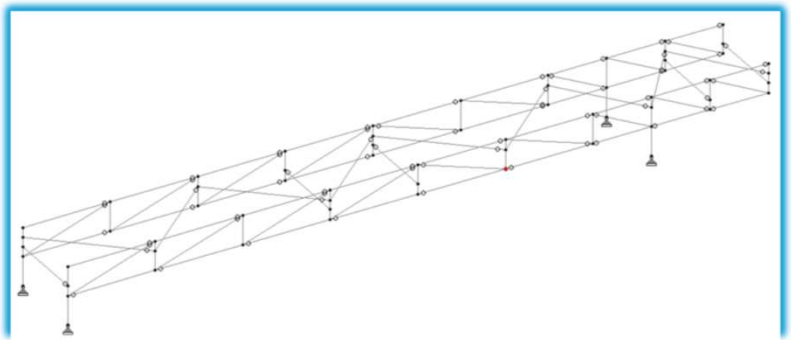

Figure 24: Pratt Truss STAAD Model [9]

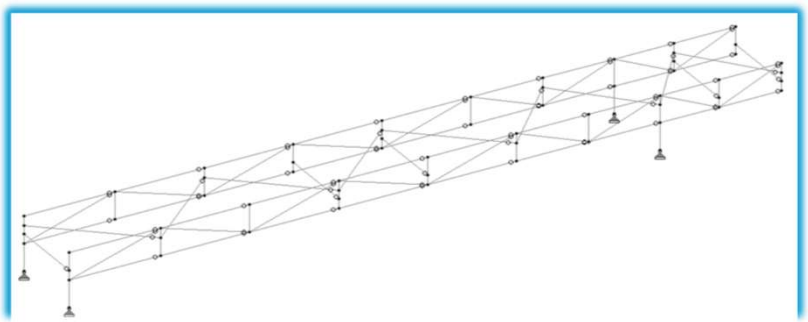

Figure 25: Warren Truss STAAD Model [9]

Final Analysis and Design

STAAD Results

- Final Analysis Results

Vertical Deflection		Sway	
Measurement Place	Y (in)	Measurement Place	Z (in)
9' 6"	0.389	12' 0"	0.063
10' 0"	0.388	23' 0"	0.077
11' 0"	0.372	24' 0"	0.078

Table 4: STAAD Results

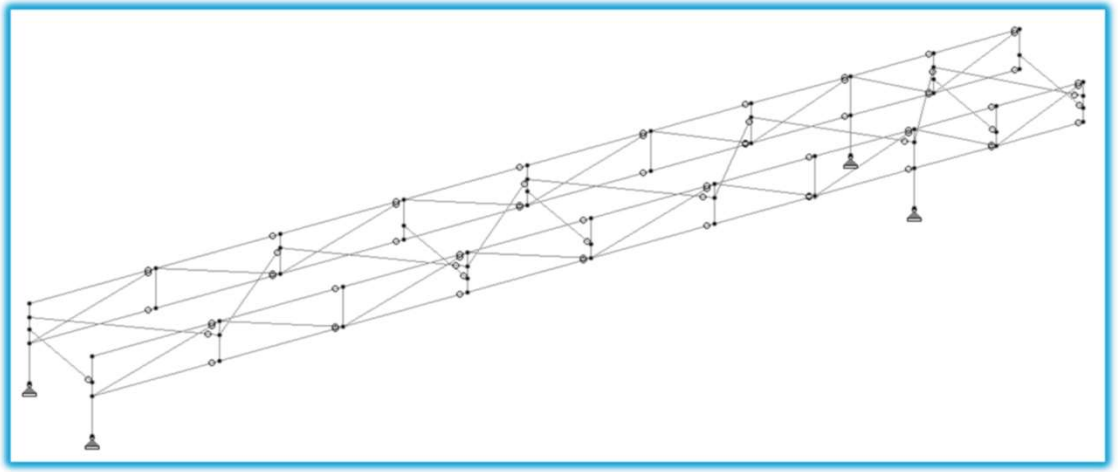

Figure 26: 3D STAAD Model [9]

Final Analysis and Design

STAAD Results Cont.

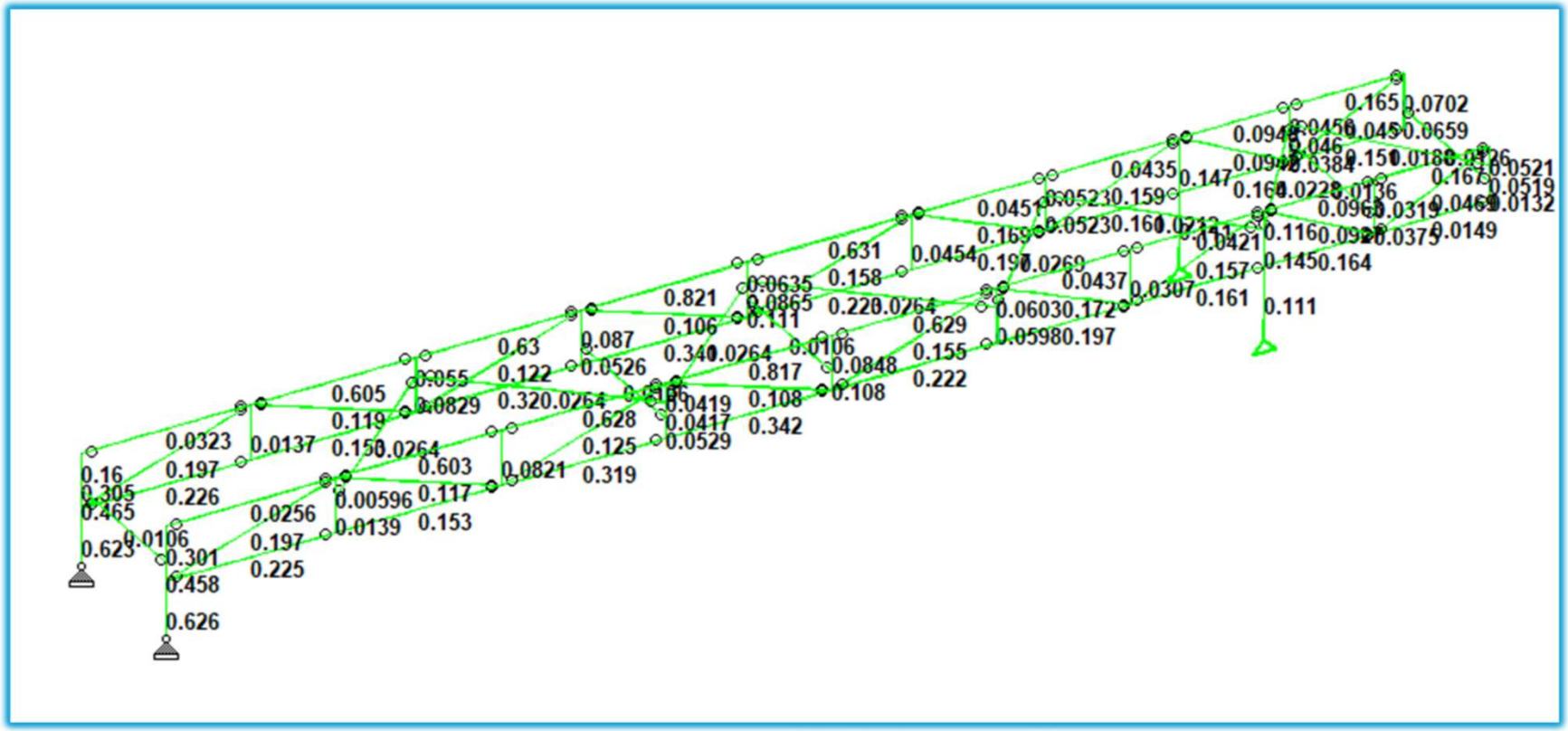

Figure 27: 3D STAAD Model with Utilization Ratio [9]

Final Analysis and Design

STAAD Results Cont.

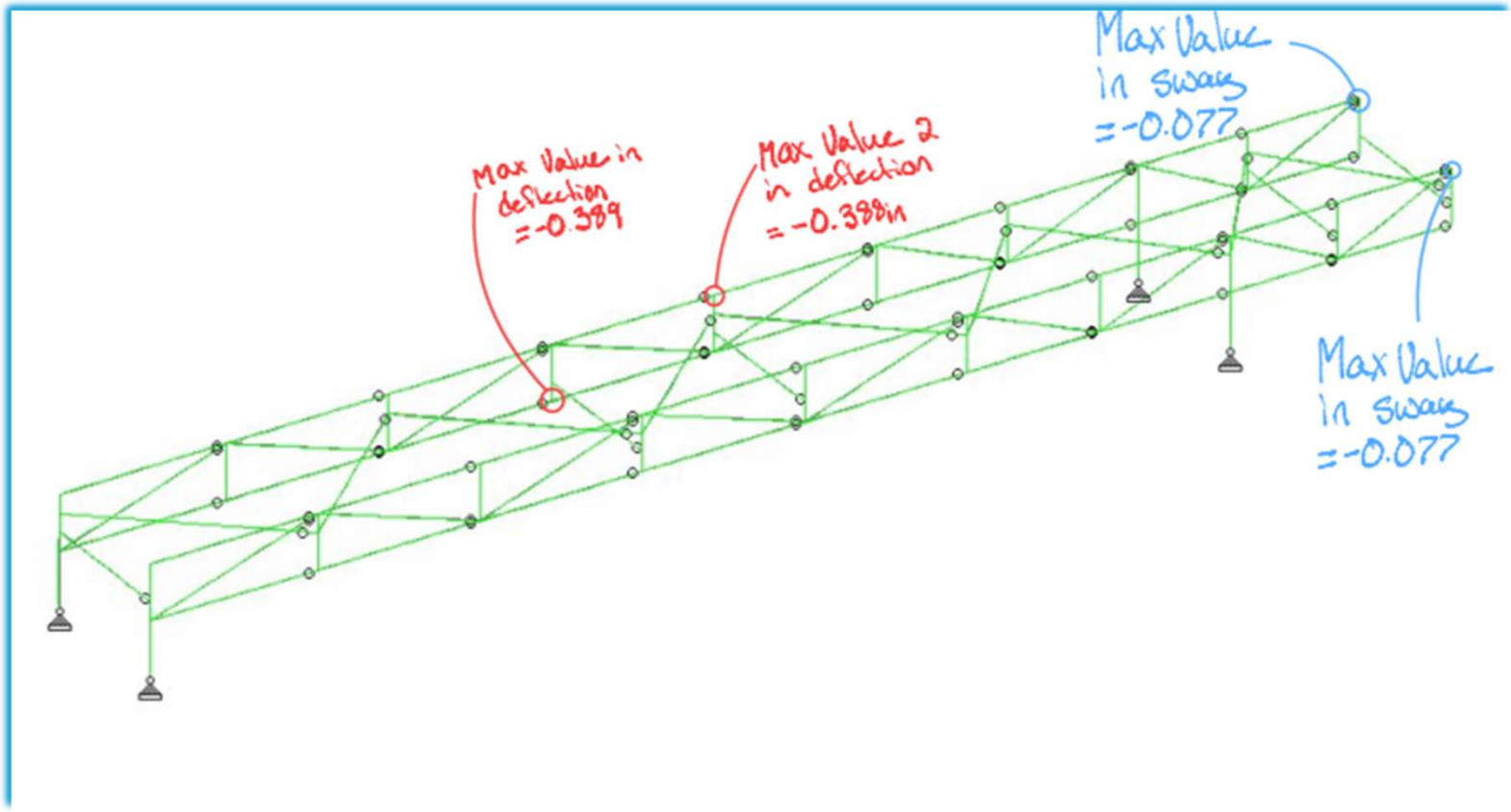

Figure 28: 3D STAAD Model Deflection Maximum Labels [9]

Final Analysis and Design

Final Member & Connection Design

- Bolt & weld calculations in Excel
  - HSS capacities & plate capacities at connections
- AISC Steel Construction Manual
  - Parts: 7, 8, 9, 10, 16
  - Part 16 sections: B, D, J, K

TABLE J2.4
Minimum Size of Fillet Welds

Material Thickness of Thinner Part Joined, in. (mm)	Minimum Size of Fillet Weld,[a] in. (mm)
To 1/4 (6) inclusive	1/8 (3)
Over 1/4 (6) to 1/2 (13)	3/16 (5)
Over 1/2 (13) to 3/4 (19)	1/4 (6)
Over 3/4 (19)	5/16 (8)

Figure 29: Table J2.4 from AISC Steel Manual [10]

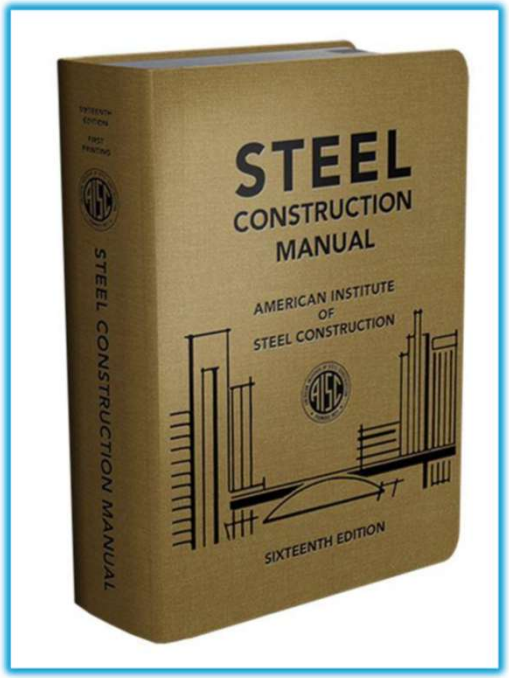

Figure 30: AISC Steel Manual [10]

Final Analysis and Design

Bolt Calculations

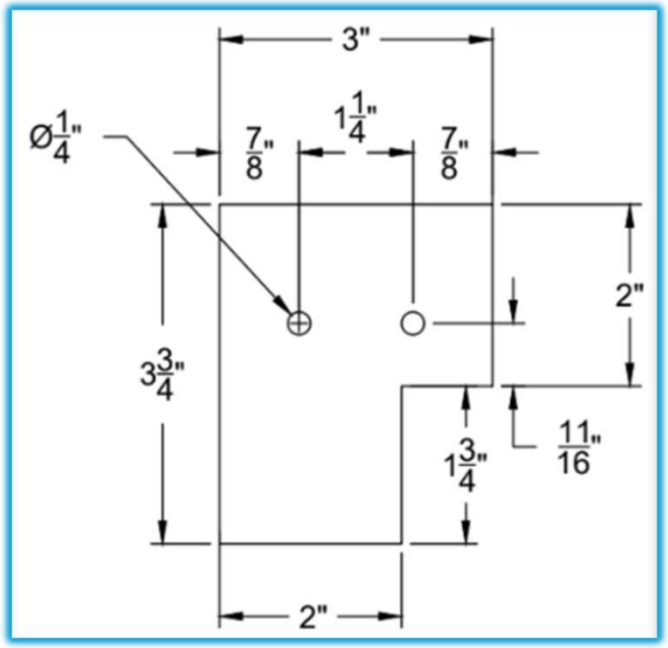

Figure 31: Connection 0.5C Detail 1 [11]

Required Demand	
Connection Demand	2.95 kip
Calculated Failure States	
Bolt Ten. Failure	2.98 kip
Bolt Shear Failure	4.47 kip
Bolt Bearing	7.31 kip/bolt
Bolt Tearing	6.40 kip/bolt
Block Shear	20.26 kip
GSY Tension	22.50 kip
NSR Tension	20.57 kip
GSY Shear	13.36 kip
NSR Shear	9.60 kip
HSS Through Bolt Bearing	8.44 kip
HSS Through Bolt Tearout	13.77 kip

Table 5: Bolt Calculations Example

Final Analysis and Design

Weld Calculations

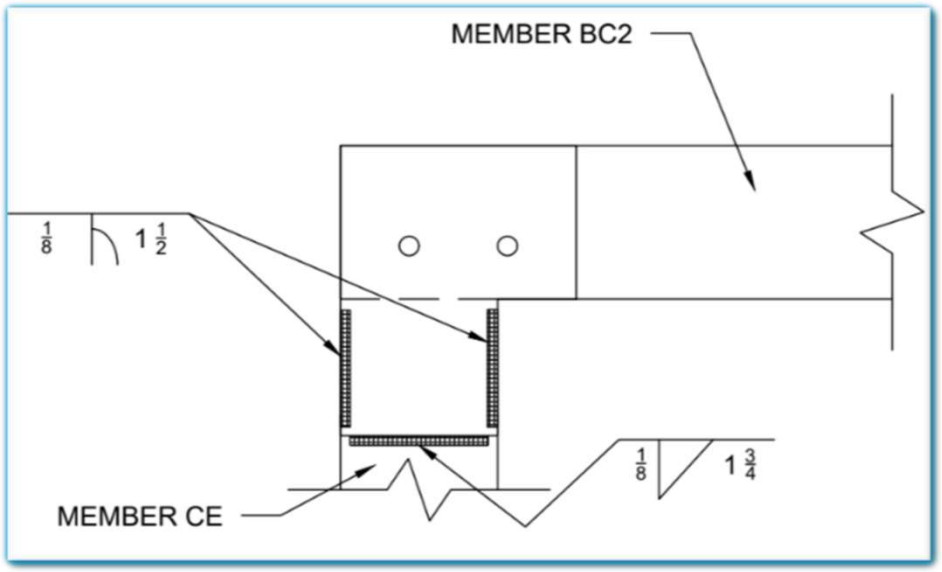

Figure 32: Connection 0.5C Detail 2 [11]

Required Demand	
Connection Demand	2.95 kips
Calculated Capacity	
Connection Capacity	3.49 kip/inch
Required Dimensions	
Weld Size Maximum	0.125 inches
Plate Length Minimum	0.5 inches
Plate Length Maximum	12.5 inches
Effective Length for HSS Members	4.34 inches
Weld Terminations	0.125 inches

Table 6: Weld Calculation Example

Final Analysis and Design

Final Decision

- Members
  - HSS 2.0x1.5x0.125
  - HSS 2.0x1.0x0.125
- Plates & Angles
  - ¼" Thick Plates
  - Angles 2x2x¼
- Bolts
  - 3/8th inch diameter
  - 1/4th inch diameter

Figure 33: Bolts & Nuts [5]

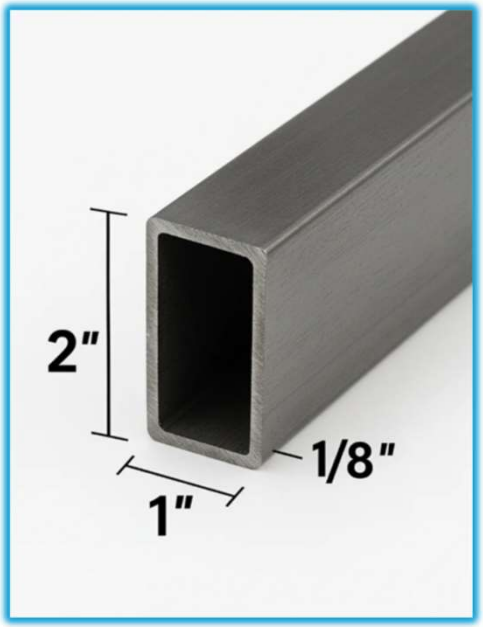

Figure 34: HSS Tube [12]

Shop Drawings

- Created in AutoCAD
- 34 pages in total

Page Number	Page Title
1	Cover Sheet
2	Project Notes
3	Profile & Elevation View
4-5	Section Cuts
6-7	Connection Keys
8	Member Key
9	Top Chord Details
10-11	Bottom Chord Details
12	Diagonal Member Details
13-14	Vertical Member Details
15	Footing Details
16-17	Lateral Bracing Member Details
18-34	Plate Details

Table 7: Shop Drawings Summary

Shop Drawings

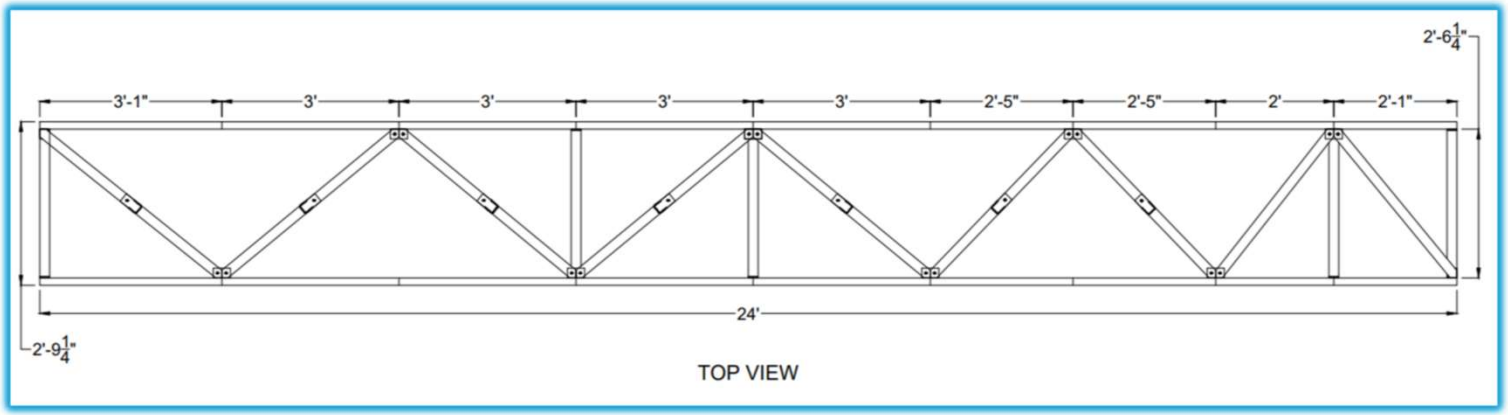

Figure 35: Shop Drawings – Elevation View [11]

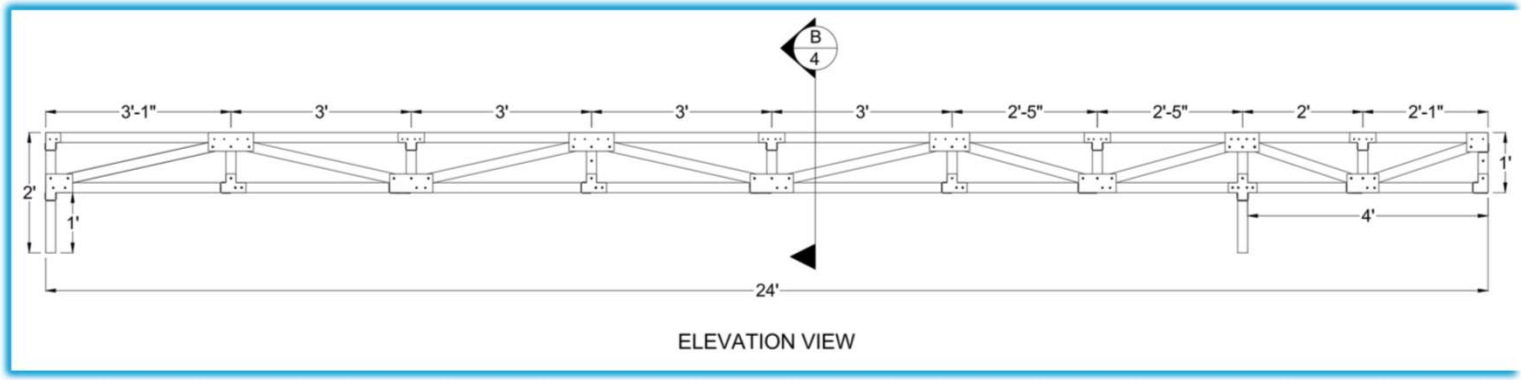

Figure 36: Shop Drawings – Elevation View [11]

Shop Drawings

TRUSS MEMBER SCHEDULE				
MEMBER	MATERIAL	CUT LENGTH	QUANTITY	TOTAL LENGTH
AA	HSS 2.0x1.5x0.12	3'-0"	4	12'-0"
AH	HSS 2.0x1.5x0.12	2'-5"	2	4'-10"
AJ	HSS 2.0x1.5x0.12	2'-1"	2	4'-2"
AK	HSS 2.0x1.5x0.12	0'-8"	2	1'-4"
BA	HSS 2.0x1.5x0.12	0'-8"	5	3'-4"
BA2	HSS 2.0x1.5x0.12	0'-8"	1	0'-8"
BA3	HSS 2.0x1.5x0.12	0'-8"	2	1'-4"
BC	HSS 2.0x1.5x0.12	3'-0"	8	24'-0"
BC2	HSS 2.0x1.5x0.12	3'-1"	2	6'-2"
BD	HSS 2.0x1.5x0.12	2'-11"	10	29'-2"
CD	HSS 2.0x1.5x0.12	0'-8"	5	3'-4"
CD2	HSS 2.0x1.5x0.12	0'-8"	3	2'-0"
CE	HSS 2.0x1.5x0.12	0'-8"	2	1'-4"
CI	HSS 2.0x1.5x0.12	2'-0"	2	4'-0"
CK	HSS 2.0x1.5x0.12	2'-1"	2	4'-2"
DD	HSS 2.0x1.5x0.12	3'-0"	4	12'-0"
EA	HSS 2.0x1.5x0.12	3'-1"	2	6'-2"
EE	HSS 2.0x1.5x0.12	1'-0"	2	2'-0"
FF	HSS 2.0x1.5x0.12	1'-0"	2	2'-0"
FH	HSS 2.0x1.5x0.12	2'-5"	2	4'-10"
FJ	HSS 2.0x1.5x0.12	2'-0"	2	4'-0"
GH	HSS 2.0x1.5x0.12	2'-4 1/4"	4	9'-5"
GI	HSS 2.0x1.5x0.12	2'-5"	4	9'-8"
IJ	HSS 2.0x1.5x0.12	1'-11 5/8"	4	7'-7 1/2"

Figure 37: Shop Drawings – Member Schedule [11]

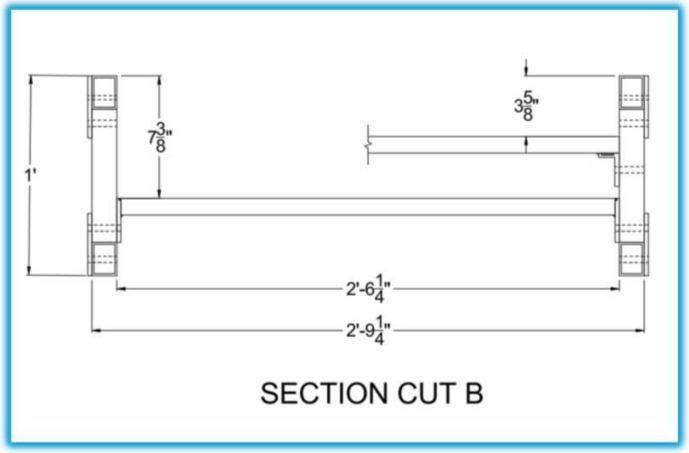

Figure 38: Shop Drawings – Section Cut B [11]

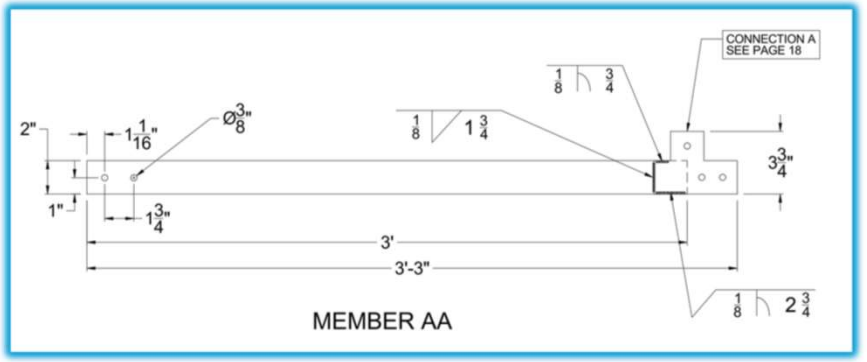

Figure 39: Shop Drawings – Horizontal Member Detail [11]

Shop Drawings

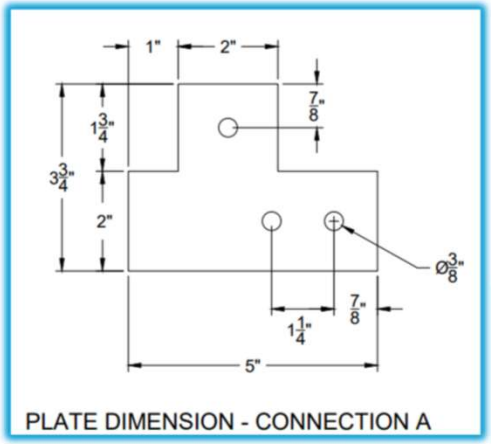

Figure 40: Shop Drawings – Plate Detail 1 [11]

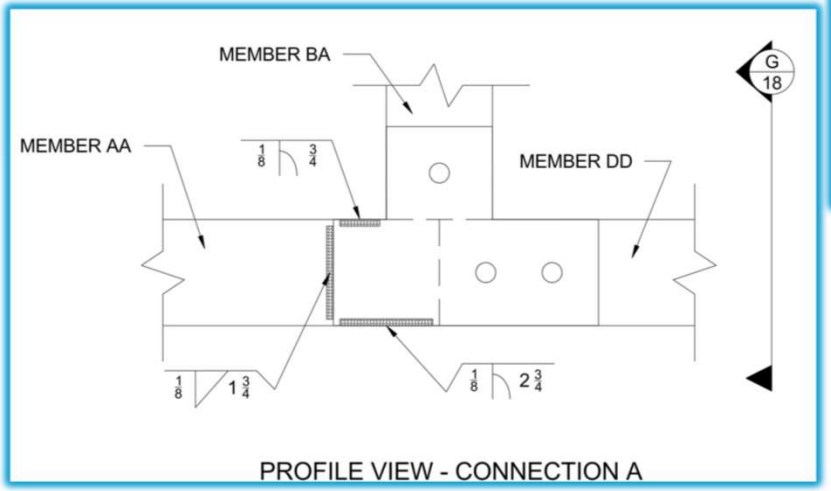

Figure 41: Shop Drawings – Plate Detail 2 [11]

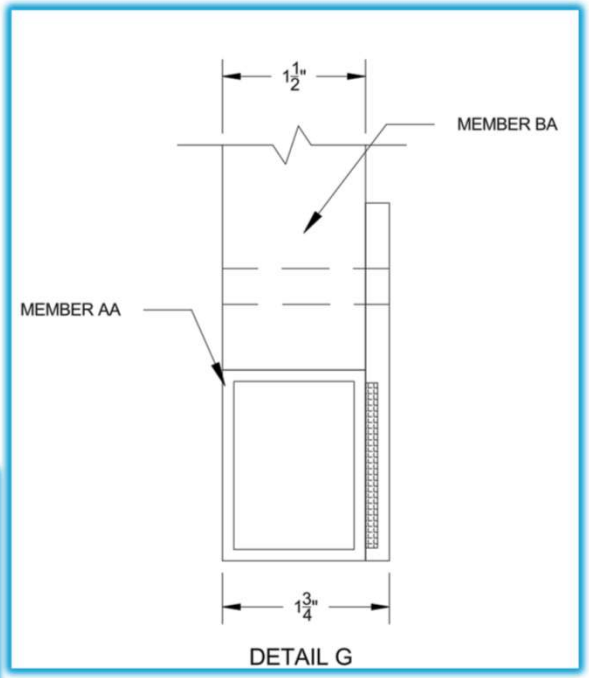

Figure 42: Shop Drawings – Plate Detail 3 [11]

Coordination & Donations

Page Steel & Copper State

- Page Steel
  - Donated members, plates, and angles
- Copper State Nuts & Bolts
  - Donated bolts and nuts

Figure 43: Copper State Logo [13]

Figure 44: Page Steel Logo [14]

Figure 45: Copper State Bolts [1]

Fabrication

- Cutting & grinding
- Welding
- Drilling holes

Figure 46: Cutting Plates [15]

Figure 47: Grinding Down Rusted Members [15]

Figure 48: Marking Plate Dimensions [15]

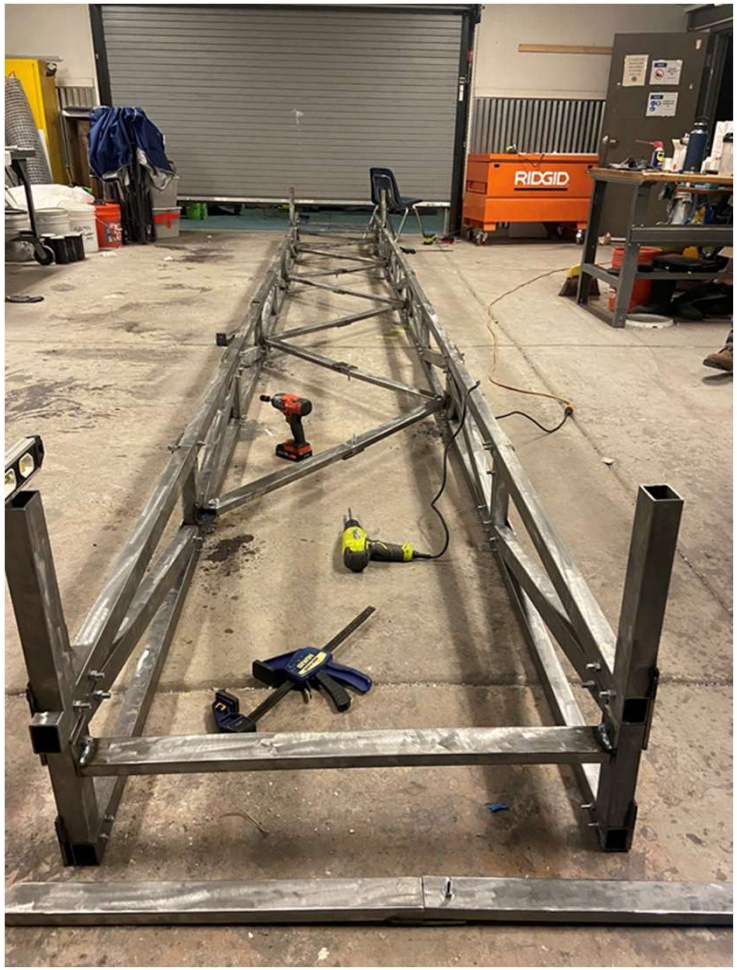

Figure 49: First Bridge Construction Result [15]

Competition

Display Day

Figure 50: Display Day Construction, North Side [16]

Figure 51: Display Day Construction, South Side [16]

Figure 52: Practice Construction [15]

Competition

Competition Day

Figure 53: Setting up Materials and Tools on Competition Day [16]

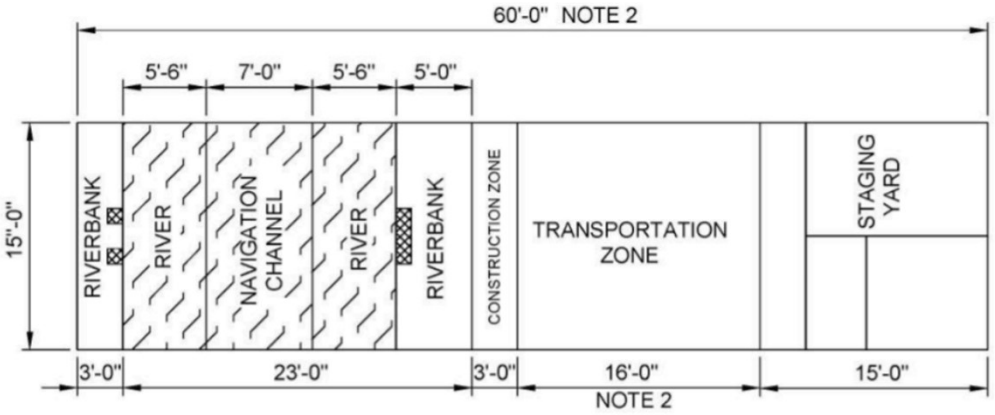

Figure 54: Construction Layout [2]

Figure 55: Connecting Top Cords [16]

Figure 57: Connecting Members with Plates [16]

Figure 56: Connecting Bottom Cords [16]

Competition

Competition Day Cont.

Figure 58: Competition Day Deflection [16]

Figure 59: Using Teamwork to Input Members [16]

Figure 60: Top Cord Construction [16]

Final Results

- Load Test:
  - 1600 lbs along midspan
    - 9'6" from left side of bridge
  - 900 lbs on cantilever

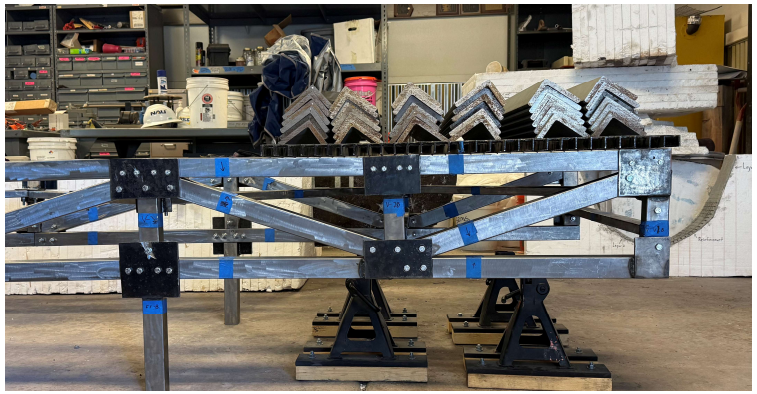

Figure 61: Loaded Cantilever [15]

Vertical Deflection Results	
Midspan	1 3/8"
Cantilever	1/16"

Table 8: Deflection Results

Figure 62: Loaded Midspan [15]

Lessons Learned

- More construction equipment practice
- Smaller members
- More welded sections

Figure 64: Banquet Team Picture [16]

Figure 63: Bridge Construction Deflection [16]

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THANK YOU!