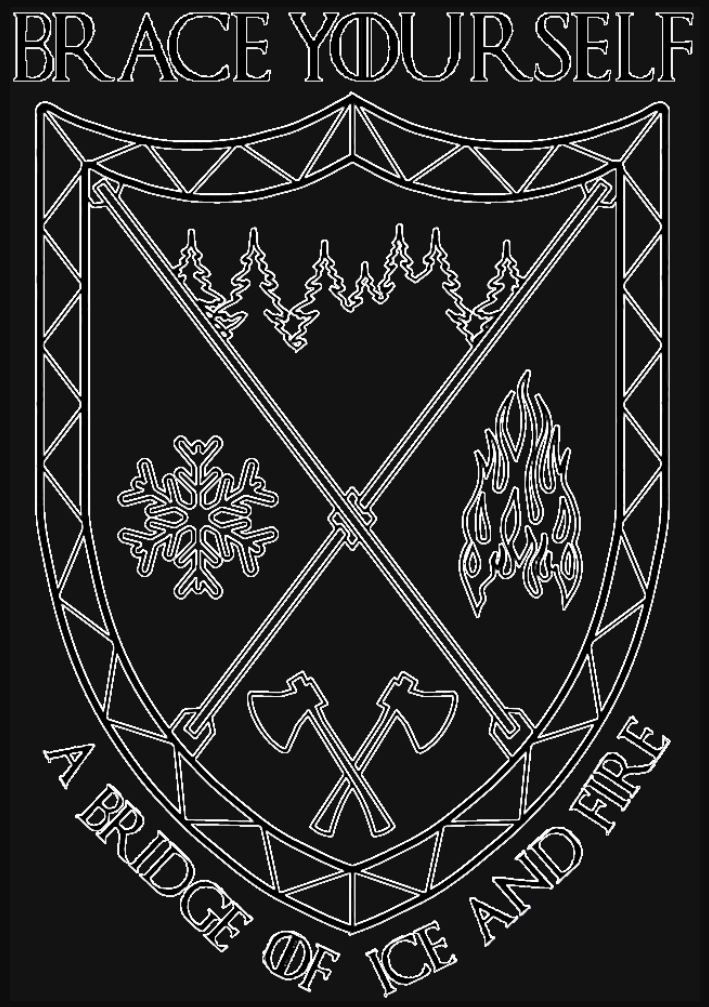


Figure 1: Team Logo

Steel Bridge Team

Final Presentation

Kayley Adams, George Beamish, Emmanuel James, Andrew Samson

April 26th, 2019

CENE 486C

Project Background

- American Institute of Steel Construction (AISC) Student Steel Bridge Competition (SSBC)
  - Conference Host: Cal Poly SLO
  - April 4th– 6th 2019
- Objective: design and build

  a 1:10 scale bridge
- Client: Mark Lamer

Figure 2: AISC SSBC Event Logo [1]

Project Understanding

- Technical Considerations
  - 50lb lateral load
  - 2500lb vertical load
- Challenges
  - All members must fit in 3’-6” x 6” x 4” box
  - All members connected by bolt and nut

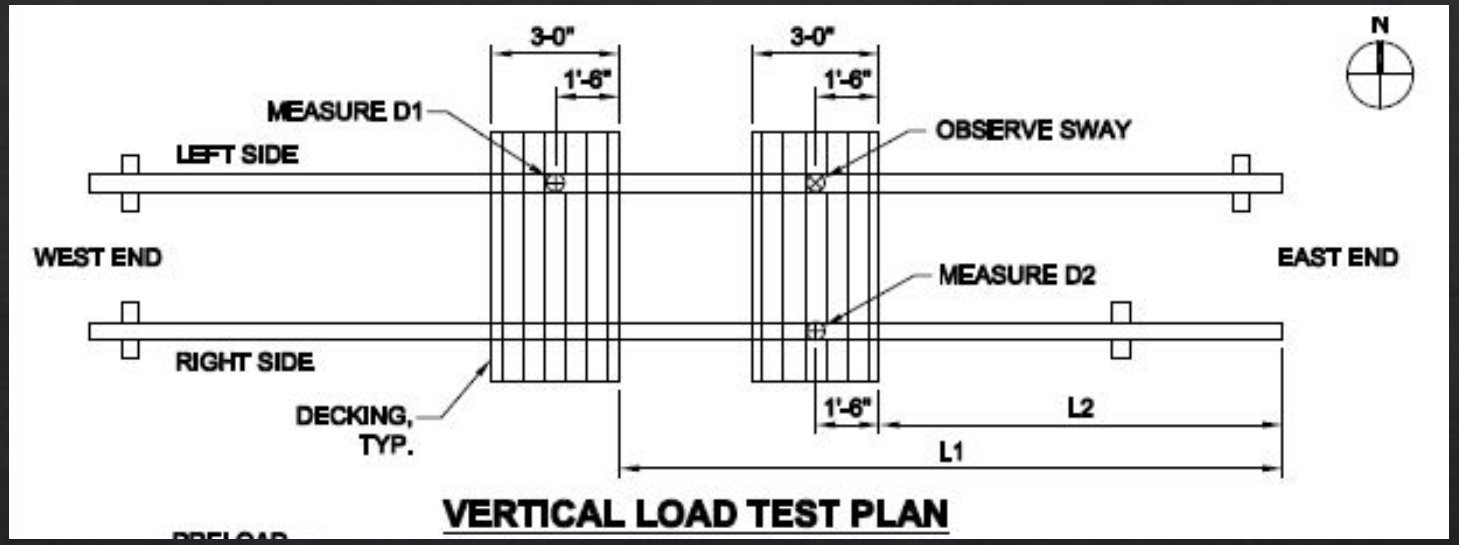


Figure 3: Vertical Load locations [1]

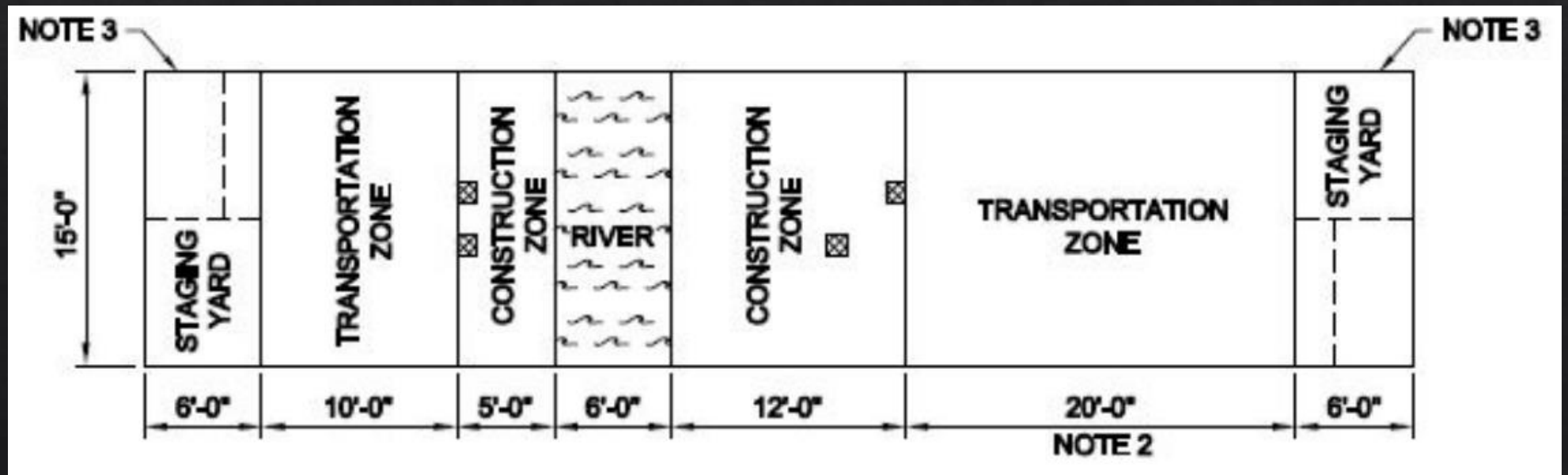
Table 1: Load combinations [1]

N	L1	L2	S
1	11’-0”	6’-0”	11’-6”
2	12’-0”	8’-0”	11’-6”
3	13’-6”	10’-0”	0’-0”
4	14’-0”	8’-4”	0’-0”
5	14’-6”	10’-8”	0’-0”
6	15’-5”	10’-5”	11’-6”

Competition Details

- Thursday April 4th – Display
  - Aesthetics only
  - Used as a tiebreaker
- Saturday April 6th – Main Competition
  - Efficiency
    - Stiffness – lateral/vertical deflection
    - Weight
  - Economy – construction time/builders
  - Overall Performance

Figure 4: Construction Site Plan for Competition [1]



Preliminary Designs

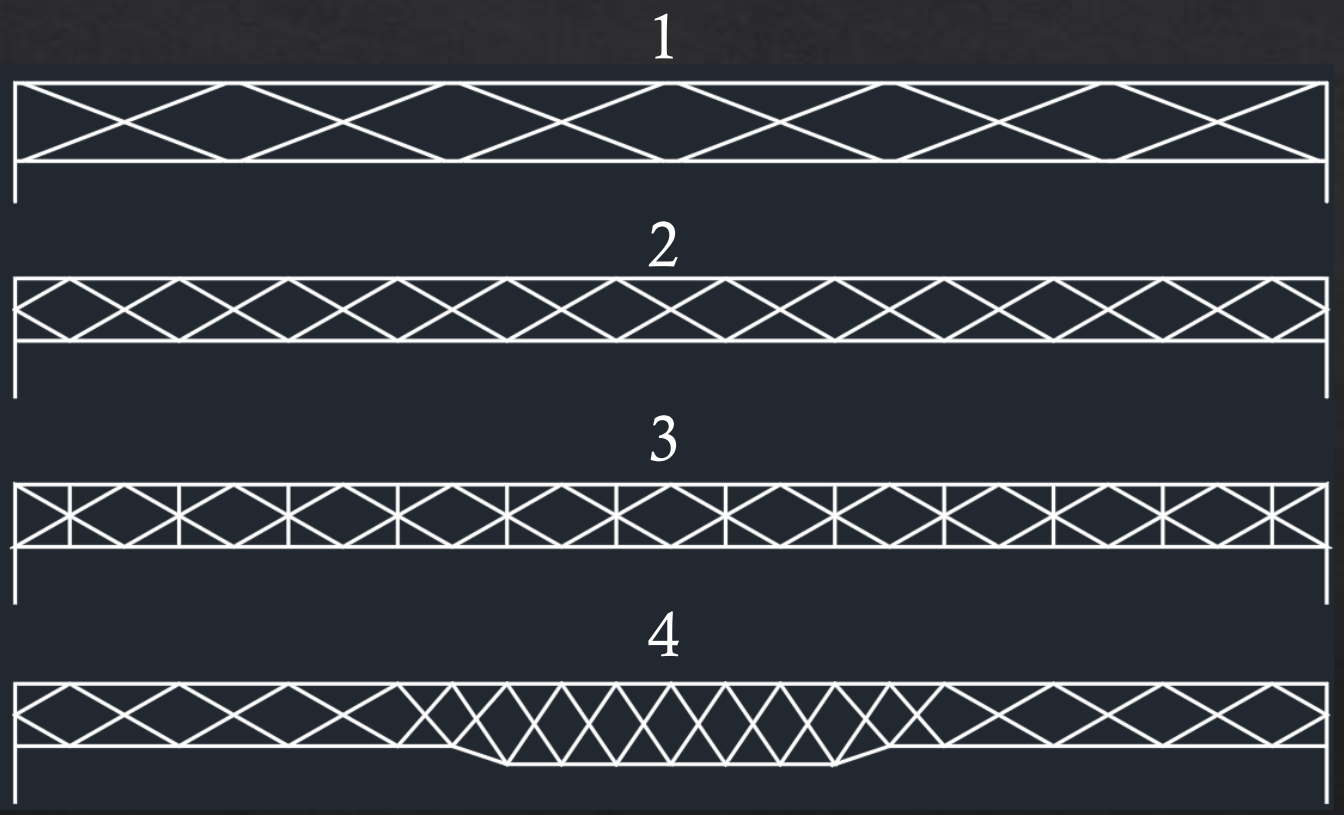


Figure 5: Preliminary Deck Trusses [2]

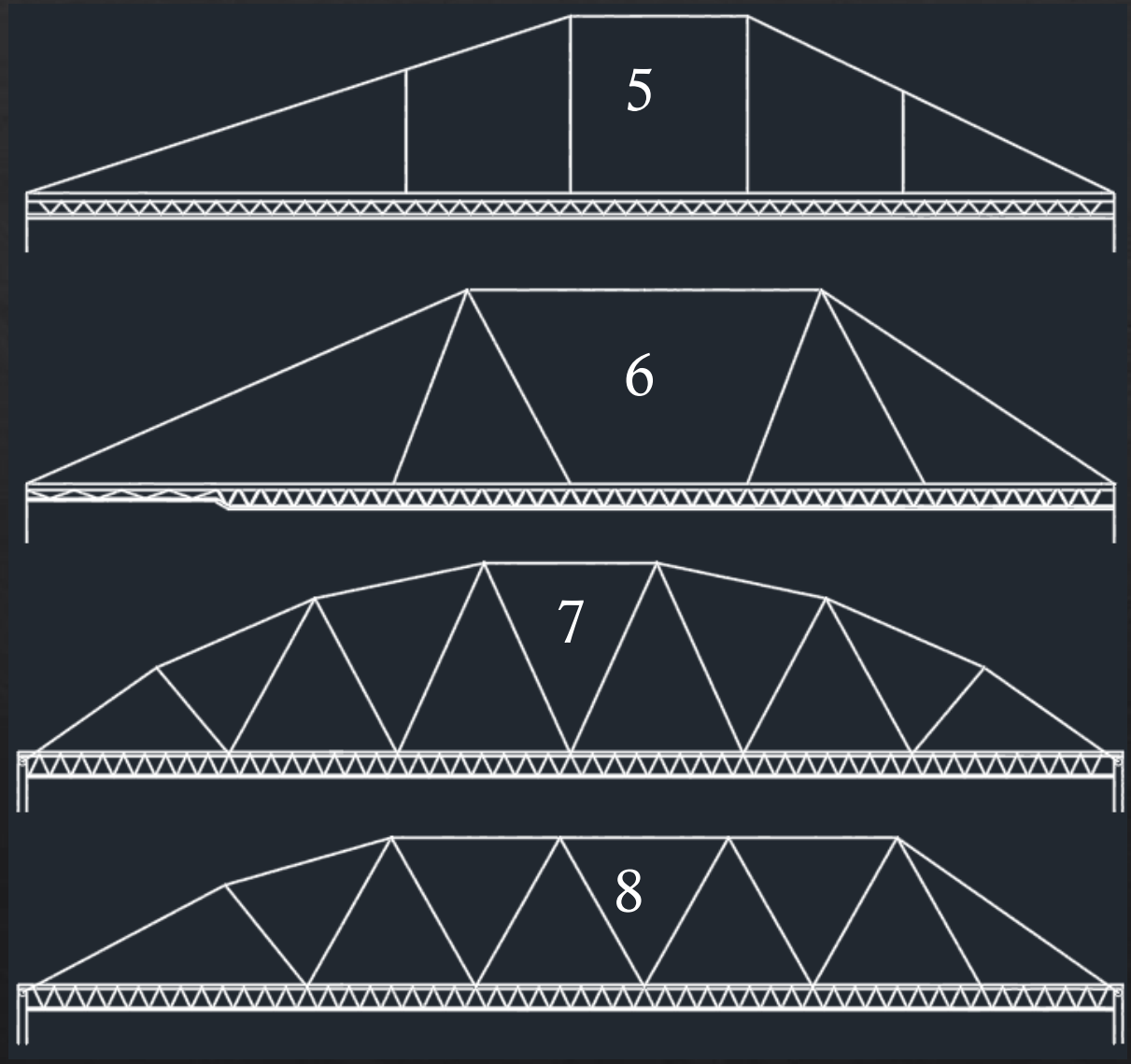
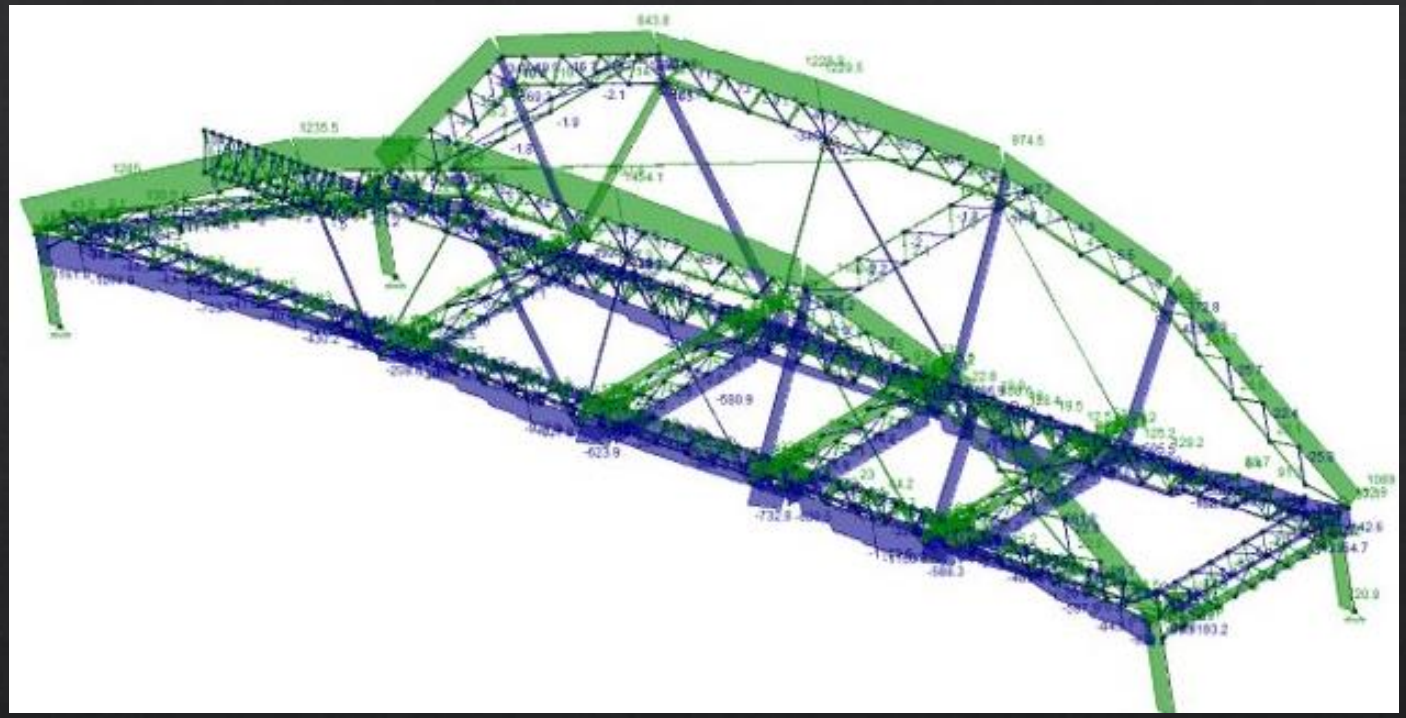


Figure 6: Preliminary Through Trusses [2]

Structural Analysis

- Vertical Deflection Design
- Lateral Deflection Design
- Design Fittings/Connections
- Final Design

Figure 7: RISA 3D Axial Force Analysis [2]



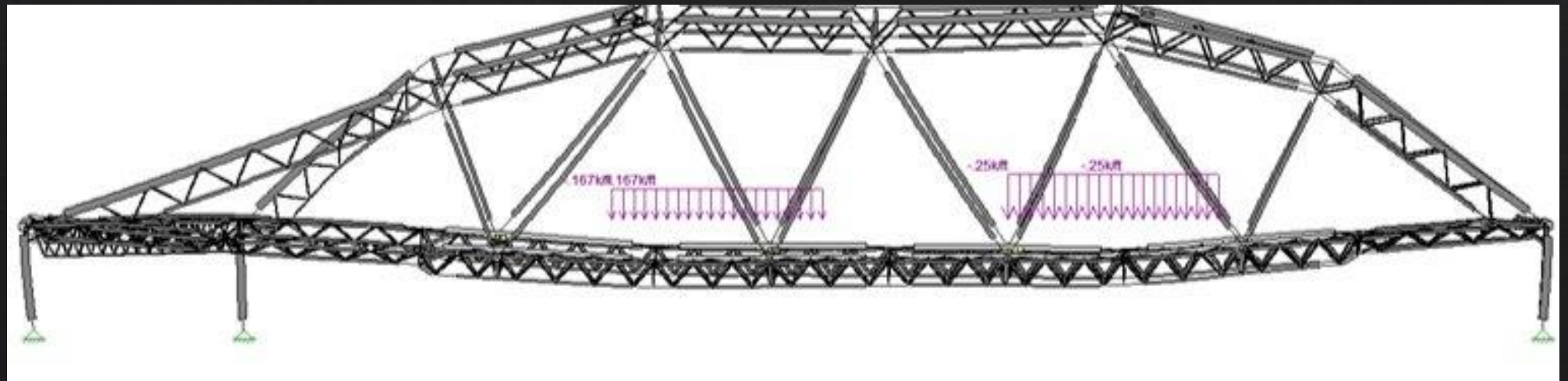


Figure 8: RISA 3D Moment and Deflection Analysis [2]

Buckling

- Flexural Buckling Stress [4]: F_{cr}
  - Elastic Critical Buckling Stress: $F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$
  - If $F_e \geq 0.44F_y$

$$F_{cr} = \left[0.658^{\frac{F_y}{F_e}}\right] F_y$$

  - If $F_e < 0.44F_y$

$$F_{cr} = 0.877F_e$$

- Maximum Allowable Compressive Force [4]: P_u
  - LRFD: $P_u = \phi_c F_{cr} A_g$
  - ASD: $P_u = \frac{F_{cr} A_g}{\Omega_c}$

F_y (psi)	36000		ϕ	0.9	
E (psi)	29000000		Ω	1.67	
L (in)	42		L/r	125.8691	
D (in)	1.05		F_e (psi)	18065.88	
d (in)	0.824		F_{cr} (psi)	15634.36	
A_g (in^2)	0.332635		P_n (lbs)	5200.534	
I (in^4)	0.037036				
r (in)	0.33368		P_u (lbs)	LRFD	ASD
				4680.481	3114.092

Table 2: Buckling Results for D=1.05in [1]

Analysis Methodology

- Members: 59
  - Components: 900+
  - Many duplicates
- ASD vs. LRFD
  - ASD: Allowable Stress Design
    - more conservative
  - LRFD: Load and Resistance Factor Design
    - more competitive

Component Size	Length (in)	Max. Comp. Force (lbs) - LRFD
1.05” OD Pipe	72	1614
	36	4680
0.50” OD Tube	42	275
	36	374
1/4” Rod	6	979
	3	1408
1/8” Rod	7	55
	4	168

Table 3: Example Buckling Results [1]

Tension

- Maximum Allowable Tensile Force: P_u
  - LRFD: $P_u = \phi_c F_y A_g$
  - ASD: $P_u = \frac{F_y A_g}{\Omega_c}$

Pipe			F_y (psi)	36000		ϕ	0.9
D (in)			A_g (in^2)	0.1131		Ω	1.67
d (in)							
			P_n (lbs)	4071.6			
HSS							
W (in)	0.5		P_u (lbs)	LRFD	ASD		
t (in)	0.065			3664.44	2438.084		

Table 4: Tension Results for 0.5" Square Tubing[1]

Bending

- Bending Stress: σ_b

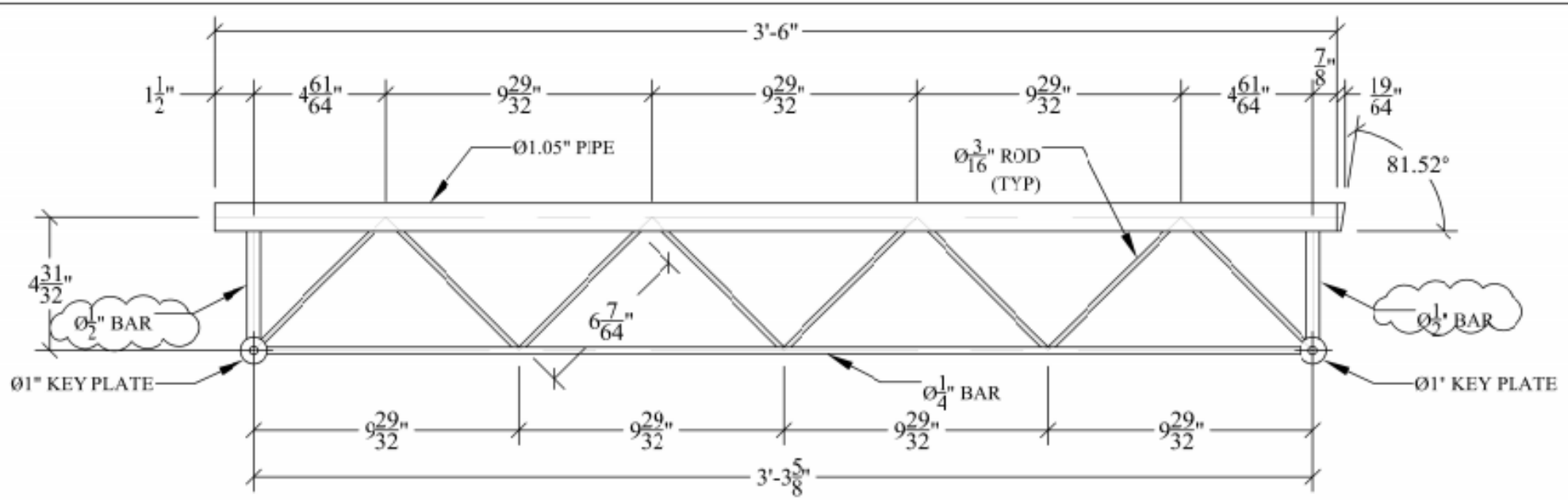
$$\sigma_b = \frac{My}{I}$$

Figure 9: Bending Failure

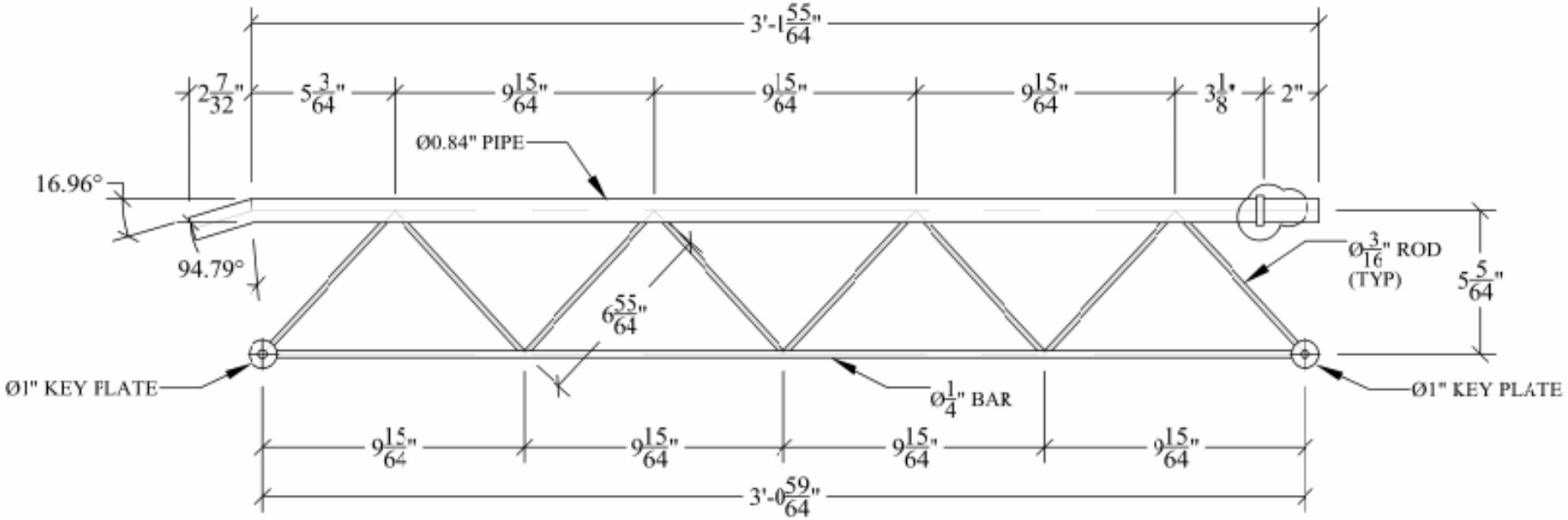
Fabrication

- Produce Construction Drawings
- Steel Preparation
- Welding
- Finish Fabrication
- Finishing

Figure 10: Finish Fabrication [2]



MEMBER AE



MEMBER AF

SHEET 1 1

Northern Arizona University Steel Bridge Team

NO | DATE | COMMENTS

DRAWN BY: GW
CHECKED BY: AJS
DATE: 07/19/19
SCALE: 3"=1'

2019 STEEL BRIDGE
MEMBERS AE & AF

Figure 11: Construction Drawings for Superstructure Members

Steel Preparation

- Cutting
- Cleaning
- Labelling

Figure 12: Finished Cut½" Sq. Tube Pieces at an Angle [2]

Figure 13: Finished Cut& Cleaned 3/16" Rods [2]

Figure 14: Andrew Preparing Steel Member for Welding [2]

Welding

Figure 15: Jigs for Superstructure Members [2]

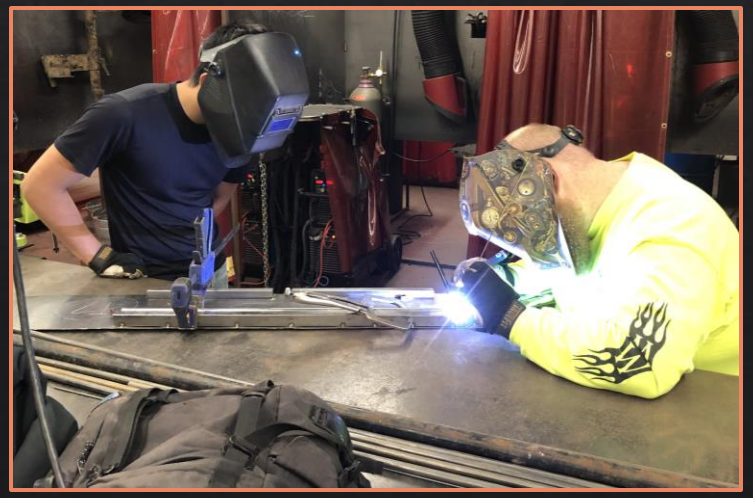


Figure 16: Andrew Lamer TIG Welding a Superstructure Member [2]

Figure 17: Welded Superstructure Members [2]

Connections

K-Zell Metals

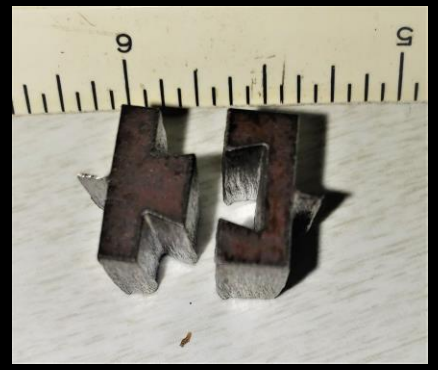


Figure 18:
Dovetail [2]

Figure 19:
Rectangle Dovetail [2]

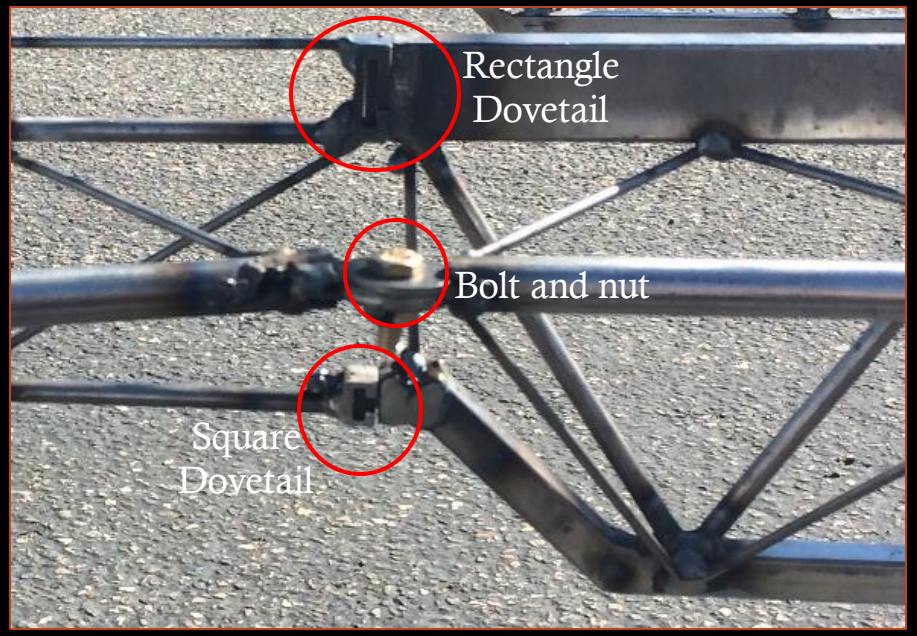


Figure 20: Connections for Two Substructure Members [2]

NAU Engineering Fabrication Shop

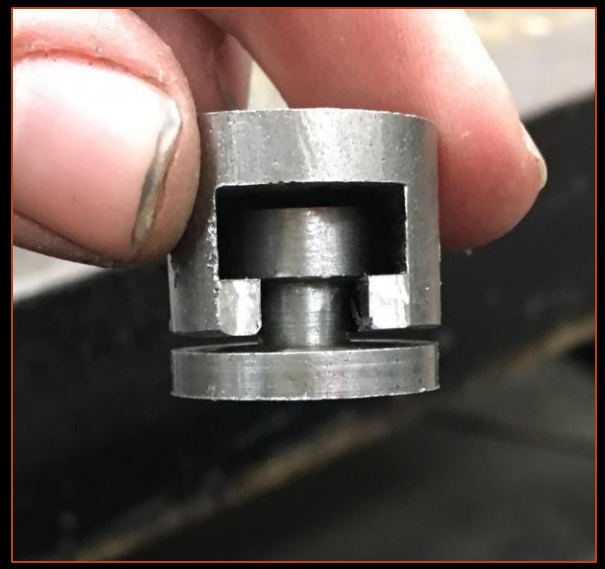


Figure 21: Round Disk Fittings [2]

Figure 22: Fixed Round Disk Fittings [2]

C.E.F.N.S Teaching & Research Machine Shop

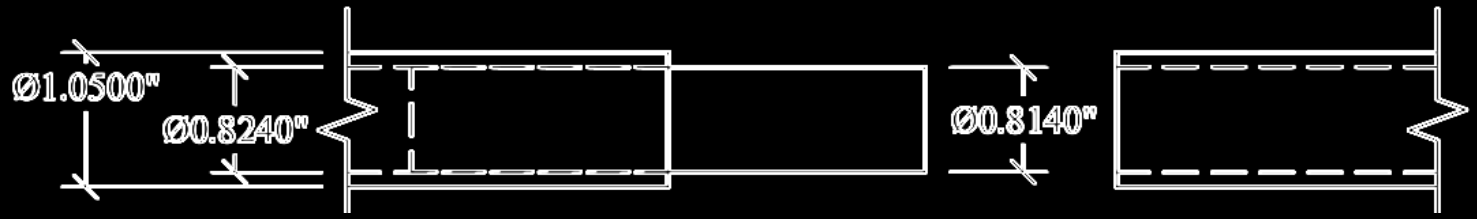


Figure 23: Side View of Sleeve Fitting for One Superstructure Member [2]

Pacific Southwest Regional Event

Figure 24: Bridge Building [2]

Figure 25: Built Bridge at Competition [2]

Figure 26: Bridge Building [2]

Final Bridge Summary

- Arched Warren Through Truss
- 59 separate members
- Total Weight = 187 lbs

Figure 27: Completed Bridge

Not Ranked		
School		NR
California Baptist University		10.3.14:
Califnoria State University Sacramento		10.8.2:
Northern Arizona University		11.1:
California State University Long Beach		11.4:
California State University, Fullerton		11.4:
University of California Los Angeles		11.4:
Cal Poly Pomona		11.5:
California State University, Fresno		11.5:
California State University, Northridge		11.5:
San Jose State University		11.5:
University of Arizona		11.5:
University of California, Irvine		11.5:
University of California, San Diego		11.5:
University of Hawaii at Manoa		11.5:
San Francisco State University		11.6:
Arizone State University		4:
University of California, Berkeley		None

Figure 28: Competition Results

Project Impacts & Takeaways

- Social
  - Involved high school students in real-world engineering project
- Environmental
  - Designed a low weight bridge resulting in less steel required
  - Laser cutting were performed by professionals eliminate harmful emissions exposure
- Economic
  - Utilized nearest mild steel distributor reduce material transport emissions
- Exposure to basic structural design & fabrication
- Familiarization of structural analysis programs
  - RISA
- Material procurement and shipping

Project Schedule

Staffing Hours

- 445 hours difference
  - Fabrication & Structural Analysis tasks were under anticipated
  - Construction Practice task were affected by Fabrication

Table 5: Proposed vs. Actual Hours for Each Task

Task Name	Number of Hours										Total Hours	
	Sr.Eng		Eng		E.I.T		Drafter		Admin			
	Prop.	Actual	Prop.	Actual	Prop.	Actual	Prop.	Actual	Prop.	Actual	Prop.	Actual
Task 1: Project Research	6	2	12	8	18	14	6	2	8	6	50	32
Task 2: Resourcing	12	8	8	4	12	8	12	8	16	12	60	40
Task 3: Structural Analysis	30	76	60	106	75	121	77	123	30	74	272	500
Task 4: Fabrication	6	59	12	75	30	94	32	95	4	57	84	380
Task 5: Construction Practice	3	0	16	3	16	3	4	0	0	0	39	6
Task 6: Project Deliverables	13	9	16	12	30	26	17	13	25	20	101	80
Task 7: Project Management	58	61	56	57	60	63	46	49	13	16	233	246
Staff Total Hours	128	**215**	180	**265**	241	**329**	194	**290**	96	**185**	**839**	**1284**

Project Cost

Table 6: Breakdown Cost of Steel Bridge Project

Item	Description	Cost per Unit ($/unit)	Units	# of Actual Units	Actual Cost	Proposed Cost	Change? (Y/N)
Staffing	Senior Engineer	150	hr	215	$ 32,250	$ 19,200	**Y**
	Engineer	115	hr	265	$ 30,475	$ 21,850	**Y**
	E.I.T	58	hr	329	$ 19,082	$ 14,558	**Y**
	Drafter	40	hr	290	$ 11,600	$ 8,160	**Y**
	Admin	32	hr	185	$ 5,920	$ 3,072	**Y**
Subtotal				1284	$ 99,327	$ 66,840	**Y**
Material	Nuts & Bolts	0.1	bolt/nut	200	$ 20	$ 20	**N**
	Steel	0.50	lb	400	$ 200	$ 200	**N**
Subtotal					$ 220	$ 220	**N**
Travel	Van Rental	60	per day	8	$ 480	$ 480	**N**
	Mileage	0.33	miles	1232	$ 407	$ 665	**Y**
	Lodging	155	night (2x)	4	$ 1,240	$ 480	**Y**
Subtotal					$ 2,127	$ 1,625	**Y**
Subcontracted Services	Welding	60	hr	380	$ 22,800	$ 1,800	**Y**
	Plate Cutting	35	plate	54	$ 1,890	$ 875	**Y**
	NAU Machine Shop	x	x	x	$ 638	x	**Y**
	CEFNS Machine Shop	x	x	x	$ 405	x	**Y**
Subtotal					$ 25,733	$ 2,675	**Y**
Total Project Cost:					**$ 127,407**	**$ 71,360**	**Y**

Thank you to our sponsors

Figure 29: Praxair

Figure 31: MUHS Welding

Figure 33: Page Steel

Figure 30: K-Zell Metals

Figure 32: Copper State Nuts & Bolts

References

[1] AISC, Student Steel Bridge Competition 2019 Rules, 2019.

[2] 2019 NAU Steel Bridge Team

[3] J. C. McCormac, Structural Steel Design, Upper Saddle River, NJ: Pearson Prentice Hall, 2008

[4] T. B. Quimby, "A BEGINNER'S GUIDE TO THE STEEL CONSTRUCTION MANUAL, 14th ed.," 30 11 2017. [Online]. Available: http://bgstructuralengineering.com/BGSCM14/Contents.htm.

Figure 34: 2019 Steel Bridge Team [2]

Disqualification Sections

- Section 10.3.14: Construction Safety
- Section 10.8.2: Construction Time
- Section 11.1: Damage
- Section 11.4: Lateral Load Test
- Section 11.5: Vertical Load Test Sequence
- Section 11.6: Unloading
- Section 4: Eligibility & Conduct

Not Ranked		
School		NR
California Baptist University		10.3.14:
Califnoria State University Sacramento		10.8.2:
Northern Arizona University		11.1:
California State University Long Beach		11.4:
California State University, Fullerton		11.4:
University of California Los Angeles		11.4:
Cal Poly Pomona		11.5:
California State University, Fresno		11.5:
California State University, Northridge		11.5:
San Jose State University		11.5:
University of Arizona		11.5:
University of California, Irvine		11.5:
University of California, San Diego		11.5:
University of Hawaii at Manoa		11.5:
San Francisco State University		11.6:
Arizone State University		4:
University of California, Berkeley		None

Project Materials

Table 4: Summary of steel requested from Page Steel

Final Steel Requisition List			
Type	**Dimension**	**Length Ordered (ft.)**	**Length Received (ft.)**
Pipe	0.540" dia. X 0.088 wall	32	**40**
Pipe	0.840" dia. X 0.109 wall	14	**20**
Pipe	1.05 dia. X 0.113 wall	36	**40**
Pipe	1.315" dia. X 0.113 wall	10	**20**
Round Tube	1/2" dia. X 0.065 wall	45	**60**
Rectangular Tube	1" x 1/2" x 0.65 wall	113	**120**
Square Tube	1/2"	30	**40**
Round Bar	1/8"	258	**260**
Round Bar	3/16"	82	**100**
Round Bar	1/4"	122	**140**
Round Bar	1/2"	6	**20**
Round Bar	9/16"	2	**20**
Square Bar	1/2"	4	**20**
Flat	1/2" x 1"	4	**20**
Sheets	**Size**		
11 GA.	1 ft. x 1 ft.		
12 GA.	1 ft. x 1 ft.		
14 GA.	1 ft. x 1 ft.		
16 GA.	1 ft. x 1 ft.		