2018 AMERICAN SOCIETY OF CIVIL ENGINEERS / AMERICAN INSTITUTE OF STEEL CONSTRUCTION

STUDENT STEEL BRIDGE COMPETITION

Undergraduate Research and Design Symposium

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April 27, 2018

PROJECT UNDERSTANDING

- For Competition in the 2018 National Student Steel Bridge Competition (NSSBC)
  - Design of 1:10 scale bridge
  - Including only steel members
- Technical Considerations
  - 50 pounds lateral load
  - 2500 pounds vertical load
- Potential Challenges
  - Member dimensions under 36”x4”x6”
  - Minimization of deflection and weight

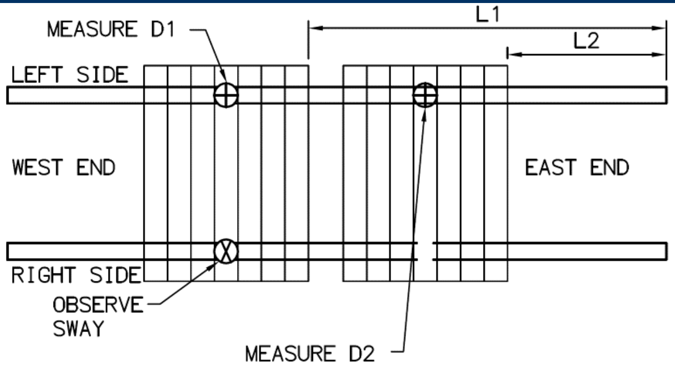

Figure 1: Vertical Load Test Top View Displaying Loading Platforms [1]

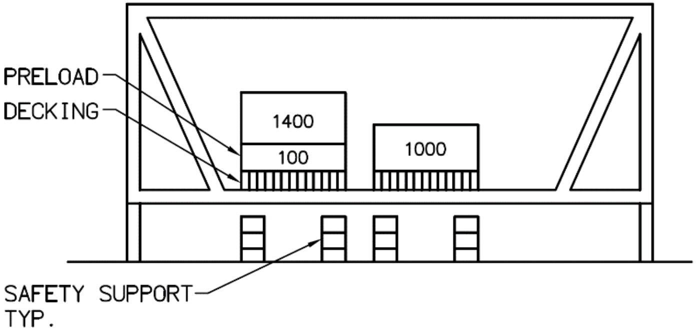

Figure 2: Vertical Load Test Side View [1]

PROJECT UNDERSTANDING

- Recognized Stakeholders
  - Mark Lamer *(Client)*
  - Thomas Nelson *(Technical Advisor)*
  - Burgeon County Transportation Commission *(Beneficiary)*
  - American Society of Civil Engineers *(Competition Host)*
  - American Institute of Steel Construction *(Competition Host)*
  - Northern Arizona University *(School Representative)*

- Competition Judging Criteria:
  - Display
  - Construction Speed
  - Lightness
  - Stiffness
  - Construction Economy
  - Structural Efficiency

AMERICAN SOCIETY OF CIVIL ENGINEERS [1]

[2]

PRELIMINARY TRUSS GEOMETRY

- Double Howe (KK) Truss
  - Simple and effective
  - Lengths of some spans were six feet long
- Parker (K) Truss
  - Maximize use of design envelope
  - Anticipated difficulties in fabrication

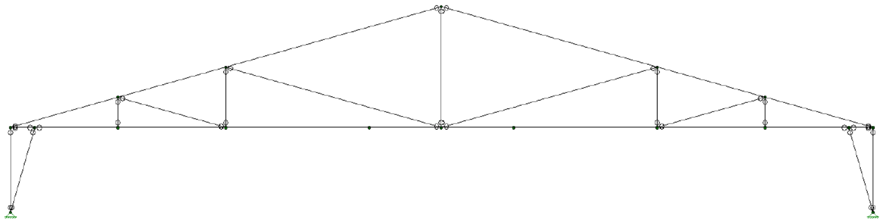

Figure 3: Double Howe (KK) Truss Side View

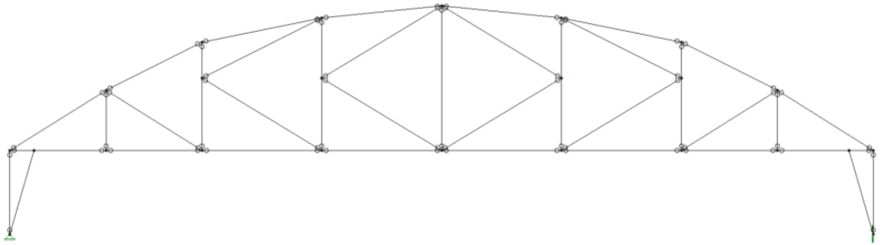

Figure 4: Parker (K) Truss Side View

CHOSEN DESIGN

- Underslung Howe Truss
  - Substantial stiffness in design
  - Fully utilizes space provided by building envelope
  - Ease of construction and fabrication

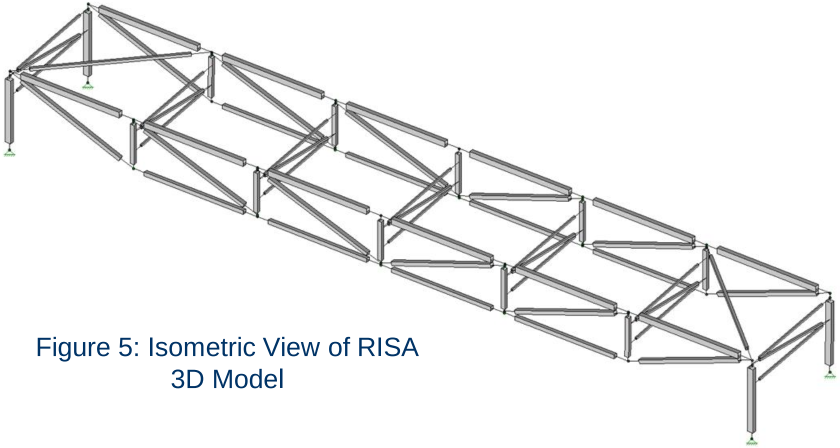

Figure 5: Isometric View of RISA 3D Model

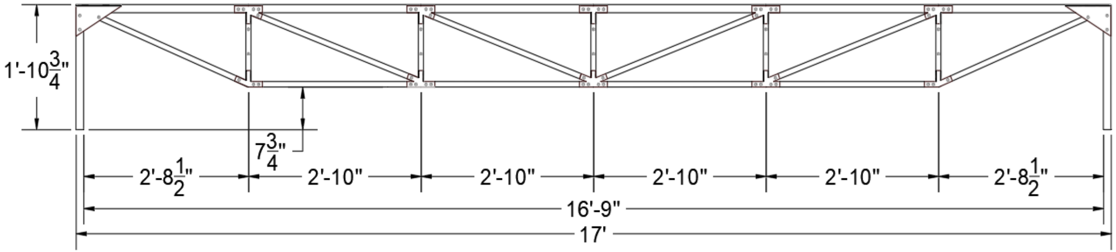

Figure 6: Side View of Bridge Design

Isaac

COMPUTER AIDED ANALYSIS

- RISA 3D Model
  - Using RISA 3D allowed for design iterations and modifications to be made easily
  - Bridge was modeled with pin-pin supports
  - Connection types were meant to represent anticipated behavior of bridge

- Loading
  - All load cases were considered, including intermediate steps in loading, for a total of 24 load cases
  - No load factors were applied

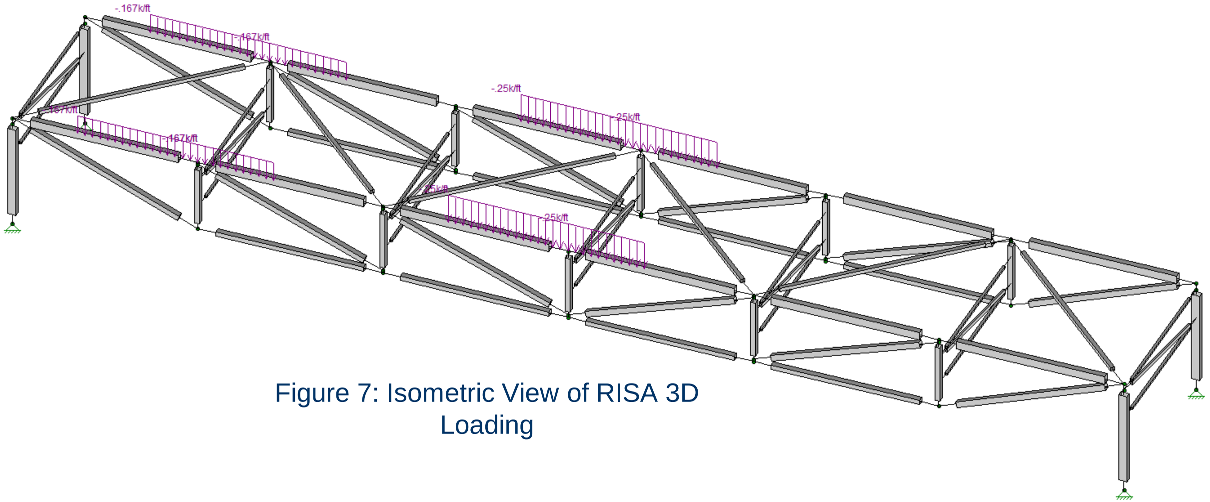

Figure 7: Isometric View of RISA 3D Loading

Isaac

FINAL DESIGN

Table 1: Final Design Material Breakdown

Member Type	Steel Grade	Thickness	Cross-Section Dimensions	Yield Strength
Top chords and footings	A513	11ga (1/8”)	1 ½” x 1” tube	72 ksi
Bottom chords, vertical, diagonals, cross-braces, and lateral diagonals	A500	16ga (1/16”)	1” x 1” ½” x ½” for cross-braces ¾” x ¾” for lateral diagonals	46 ksi
Steel plate	A606-4 GR50	11ga & 16ga	NA	> 60 ksi

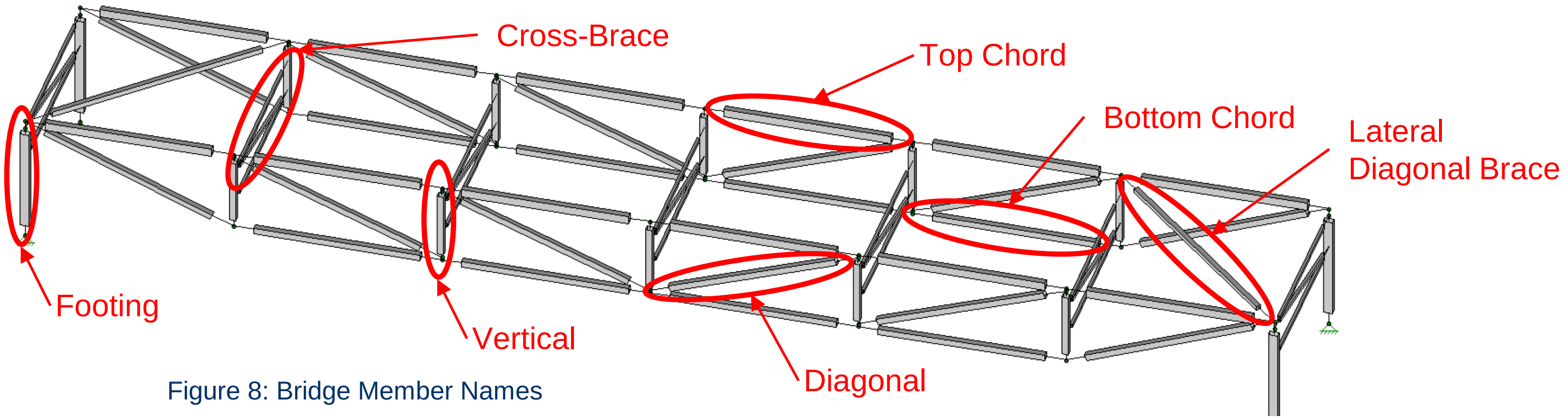

Figure 8: Bridge Member Names

FINAL DESIGN

Table 2: Final Design Material Strength

Member Type	Calculated Maximum Axial Force	Calculated Max Moment	Calculated Maximum Stress	Yield Strength	Euler Buckling Load	Factor of Safety
Top chords and footings	3.8 kip (compression)	253 lb-ft	31.7 ksi	72 ksi	32.3 kip	1.9
Bottom chords	3.3 kip (tension)	None	23.6 ksi	46 ksi	NA	1.9

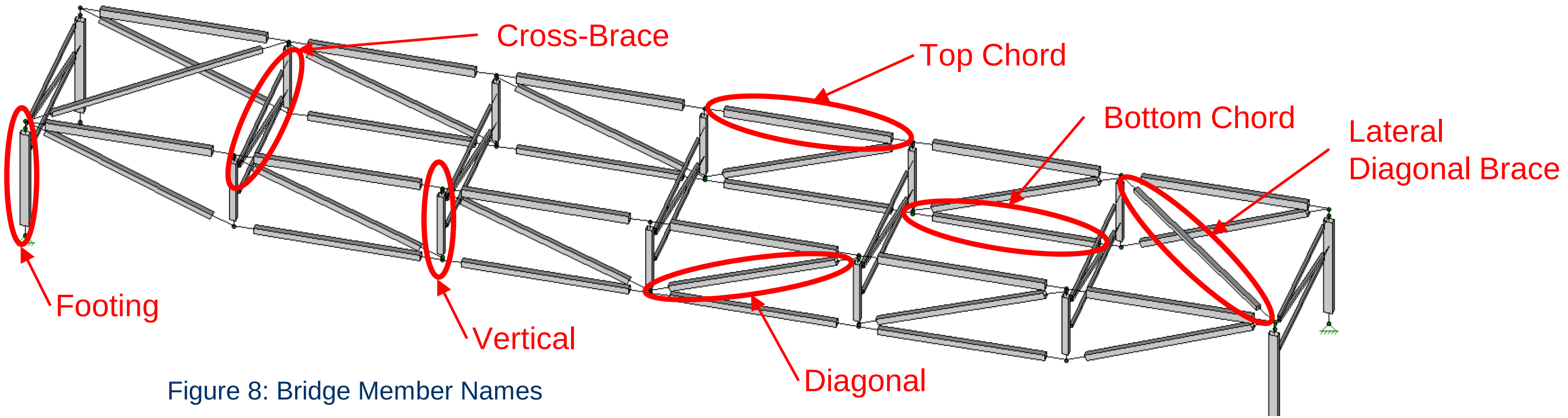

Figure 8: Bridge Member Names

CONNECTION DESIGN

- Gusset Plate Connections
  - Common in trusses
  - Ease of implementation
  - Simple and versatile in design
- Moment Connections
  - Created by two bolts in a row
  - Modelled as pins conservatively

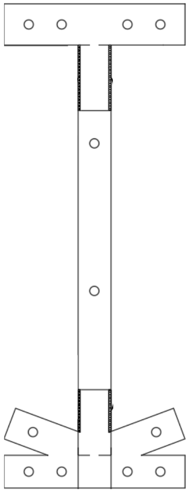

Figure 9: Example of Vertical Truss Member

Figure 10: Fabricated Vertical Truss Member with Welded Plates
Photo by: Matthew Parrish

Matt

CONNECTION CALCULATIONS

Table 3: Relevant Connection Capacities Calculated in Accordance with AISI S100

Property	Strength	Units	Section of Code [4]
Tension Capacity	11.2	kip	D1
Bolt Shear Capacity	4.47	kip	J3.4
Block Shear	42.3	kip	J6.3
Tensile Rupture	11.3	kip	J6.2

- Compliance with AISI S100
- Largest axial force: 3.8 kips
- Steel plate donation was considerably stronger steel than anticipated

Matt

FABRICATION

Figure 11: Lining Up Truss Members
Photo By: Isaac Block

Figure 12: Preparing for Drilling Bolt-Holes
Photo By: Isaac Block

Figure 13: Completed Trusses and Footings
Photo By: Isaac Block

FABRICATION – COMPLETION

Bridge summary:

- 60 members
- 148 bolts
- 160 lb total weight
- Maximum theoretical vertical deflection of 0.42 inches

Figure 14: Completed Bridge
Photo By: Isaac Block

CONSTRUCTION

First construction attempt:

- Two builders
- Rules not fully observed
- Time of construction: 1:19:28

Construction After Practice:

- Six official practice builds
- Full build team of four builders
- Rules fully observed
- Best practice time: 0:21:47

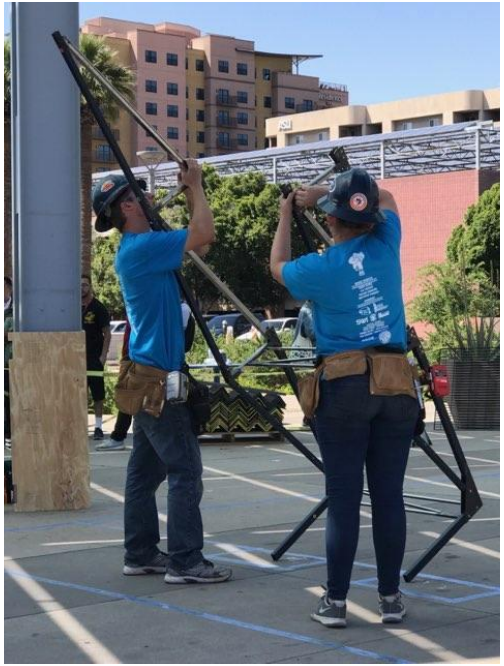

Figure 15: Construction at 2018 PSWC
Photo By: Dionne Parrish

PACIFIC SOUTHWEST CONFERENCE

Figure 16: Vertical Loading
Photo By: Dionne Parrish

Figure 17: Display Day
Photo By: Ian Connair

Figure 18: Timed Construction
Photo By: Dionne Parrish

Ian

DEFLECTION RESULTS

Table 4: Aggregate Deflection Results

	Allowable	Calculated	Actual
Vertical (2,500 lb)	3”	0.54”	0.70”
Lateral (50 lb)	1”	0.07”	~ 0.13”

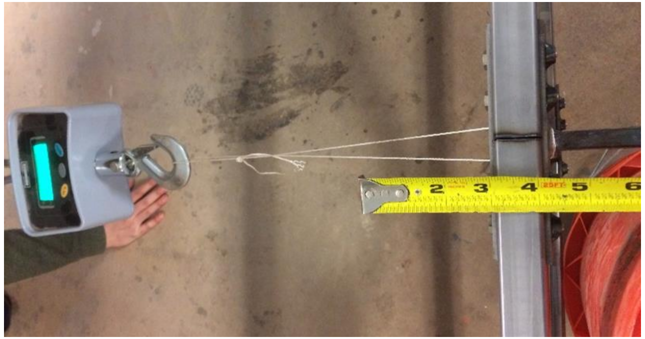

Figure 19: Lateral Load Test
Photo By: Isaac Block

COMPETITION RESULTS

ACTUAL RESULTS

Display: *3rd Place*

Stiffness: *4th Place*

- 0.7” aggregate deflection

Lightness: *5th Place*

- Before penalties: 160 lb
- After penalties: 279 lb

Structural Efficiency: *4th Place*

- $2,895,000

Construction Speed: *9th Place*

- Before penalties: 37 minutes
- After penalties: 187.75 minutes

Construction Economy: *8th Place*

- $65,712,500

Overall: *8th Place*

- $68,607,500

PRACTICE RESULTS

Display: *3rd Place*

Stiffness: *4th Place*

- 0.7” aggregate deflection

Lightness: *5th Place*

- Before penalties: 160 lb
- After penalties: 279 lb

Structural Efficiency: *4th Place*

- $2,895,000

Construction Speed: *5th Place*

- Before penalties: 21.78 minutes
- After penalties: 25 minutes

Construction Economy: *4th Place*

- Approximately $7,000,000

Overall: *4th Place*

- Approximately $9,895,500

Ian

PROJECT COST

Table 5: Anticipated and Actual Labor Hours and Cost

Task	Anticipated Task Total Hours	Anticipated Labor Cost ($)	Actual Task Total Hours	Actual Labor Cost ($)
1: Research	33	$2,125	33	$2,125
2: Fundraising	8	$630	8	$630
3: Analysis	178	$14,760	243	$19,635
4: Fabrication	156.5	$11,738	203	$15,188
5: Construction Practice	63	$4,975	63	$4,975
6: Competition	69	$4,335	71	$4,425
7: Displaying Results	63.5	$4,890	115	$8,055
8: Project Management	157	$11,330	149	$10,850
Staff Total	**Total Hours:**	**728**	**Total Hours:**	**885**
Staff Total Cost ($)	**Total Cost:**	**$54,800**	**Total Cost:**	**$65,883**

PROJECT COST

Table 6: Anticipated and Actual Project Cost Summary

Item	Cost per Unit ($/unit)	Units	# Units	Anticipated Cost	Actual Cost
Total Personnel Cost	-	-	-	$54,800	$65,833
Steel	~ 0.50	pounds	500	$250	$0
Welding	70	hours	45	$3,100	$0
Van Rental	80	day	4	$320	$320
Lodging	30	room/person/night	12	$360	$360
Total				**$59,000**	**$66,513**

PROJECT SCHEDULE

Table 7: Project Schedule Summary

Task	Proposed Start Date	Proposed End Date	Actual Start Date	Actual End Date
1.0 Research	9/5/2017	4/12/2018	9/5/2017	4/12/2018
2.0 Fundraising	12/22/2017	4/12/2018	9/29/2017	3/30/2018
3.0 Analysis and Design	9/19/2017	12/21/2017	9/19/2017	1/19/2018
3.1 Member Design	9/19/2017	11/20/2017	10/2/2017	12/8/2017
3.2 Connection Design	10/15/2017	12/21/2017	11/6/2017	1/19/2018
4.0 Fabrication	1/15/2018	3/25/2018	1/15/2018	3/27/2018
4.1 Member Preparation	1/15/2018	2/24/2018	1/15/2018	3/2/2018
4.2 Welding	2/24/2018	2/24/2018	2/24/2018	2/24/2018
4.3 Fine Tuning	2/25/2018	3/25/2018	3/5/2018	3/25/2018
5.0 Construction Practice	3/26/2018	4/13/2018	3/30/2018	4/13/2018
6.0 Competition	3/26/2018	4/14/2018	3/26/2018	4/14/2018
6.1 Competition Preparation	3/26/2018	4/6/2018	4/2/2018	4/10/2018
6.2 Competition	4/12/2018	4/14/2018	4/12/2018	4/14/2018
7.0 Displaying Results	3/19/2018	4/29/2018	4/16/2018	4/29/2018

CONCLUSION

Project Takeaways & Impacts

- Exposure to structural design and fabrication
- Learning to use RISA 2D and 3D
- Compose shop plans in order to communicate project with advisors, clients, and outsourced resources
- Navigating the AISC Steel Code
- Communicating with companies regarding material requests
- Design within specific rules and regulations

Figure 20: Team Picture After Load Testing
Photo By: Dionne Parrish

Taylor

REFERENCES

[1] Available: https://library.ucf.edu/wp-content/uploads/sites/5/2015/12/ASCE-LOGO_0.jpg

[2] Available: https://www.aisc.org/globalassets/aisc/images/logos/aisc_logo-180.png

[3] Student Steel Bridge Competition 2018 Rules, 1st ed., ASCE / AISC, 2017.

[4] American Iron and Steel Institute North American Specification for the Design of Cold-Formed Steel Structural Members, 2016.

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