Truss Bridge Design Project

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An brief overview will be given of the entire project, including background info, methodology, testing, conclusions and future recommendations.

Introduction

A new truss bridge to carry a two-lane highway across a river valley was designed spanning 44 meters. Problems include the cost and overall strength and safety rating of the structure. Force : Strength ratio and Safety rating were determined. Several different truss designs were tested under load (lab and software) to determine which was the best.

History of Truss Bridges

- 16th century Switzerland
- Claude-Louis Navier force calculations (Gasparini and Provost 22)
- Late 19th century American boom (TN.g
- Early 1900s fade

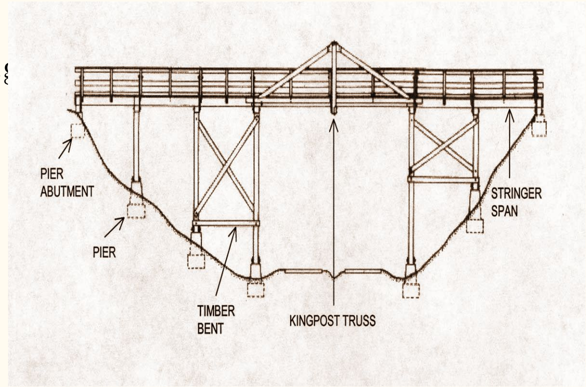

Fig 1 shows a generic truss bridge
(Source: “What is a truss bridge”, TN.gov)

Warren Truss

- James Warren and Willoughby Monzon (1848)
- Made up of equilateral triangles (see fig 2)
- Left beam in compression
- Right beam in tension (Guise 34)
- Fink/long variations

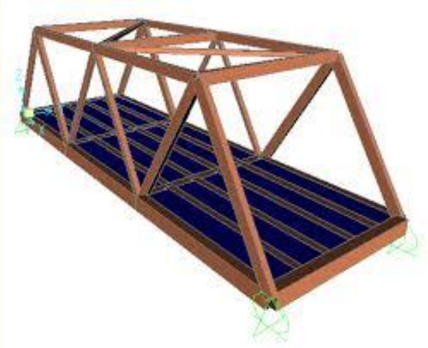

Fig 2 shows a Bridge using the Warren Truss Design (Source: Herbudiman, B., et al. 5)

Pratt Truss

- Thomas and Caleb Pratt (Historic Bridge Patents
- Diagonals point towards center of bridge (see fig 3)
- Diagonals experience tension, verticals experience compression
- Each truss can span 250ft (Waddell 468)

Fig 3 shows the Pratt Truss (Source: History of Bridges)

Pennsylvania Truss

- Pennsylvania, 1875
- Polygonal top chords (see fig 4)
- Very popular up to the 1930s (NCDOT)
- Variation of the Pratt Truss (Bridge Basics)

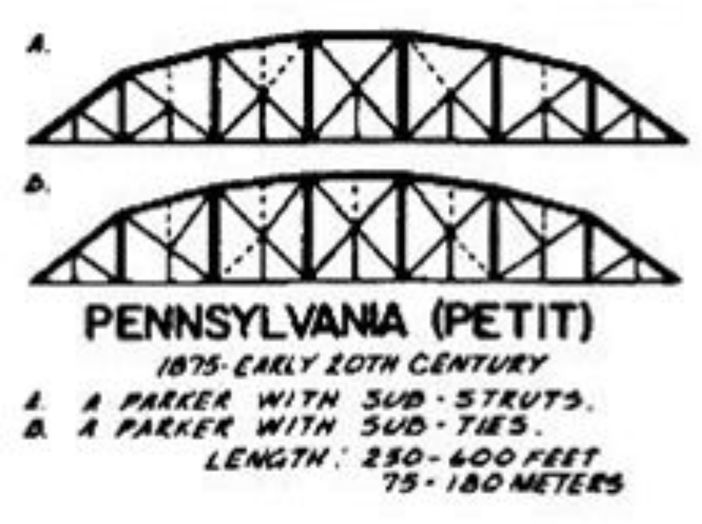

Fig 4 Shows the Pennsylvania Truss Design (Source: HAER)

Parker Truss

- Used for larger spans (200-300 feet) and heavier loads. (Adeli 14)
- Designed by C. H. Parker and is very similar to the Pratt. (see fig 5)
- Uses diagonal struts in tension and vertical struts in compression except for the hip verticals.
- Known as a camelback truss.

Fig 5 shows the Parker Truss (Source: NCDOT)

Additional Background Info

- An abutment is the end of a bridge, where they connect to land.
- A pier is a concrete post driven into the ground to support the bridge.
- Truss structures are used for space grid structures, lighting systems, cameras, speakers, and more.
- Truss systems are getting more sophisticated to increase reliability and efficiency.(Christine 449)

Lab Testing

Procedure

- Truss design was sketched in logbook first (see fig 6)
- Truss was constructed using PASCO structural beams (see fig 7)

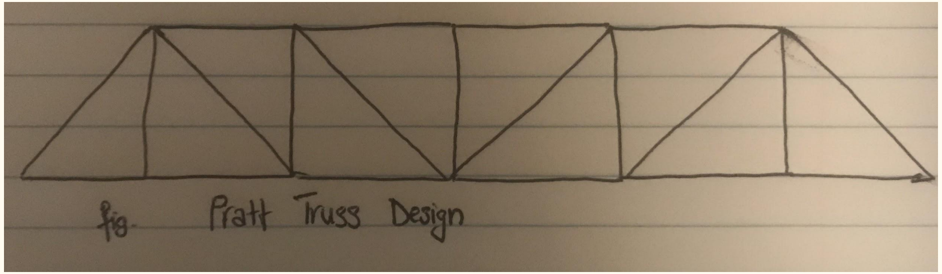

Fig 6 Shows the logbook sketch prior to going to the lab

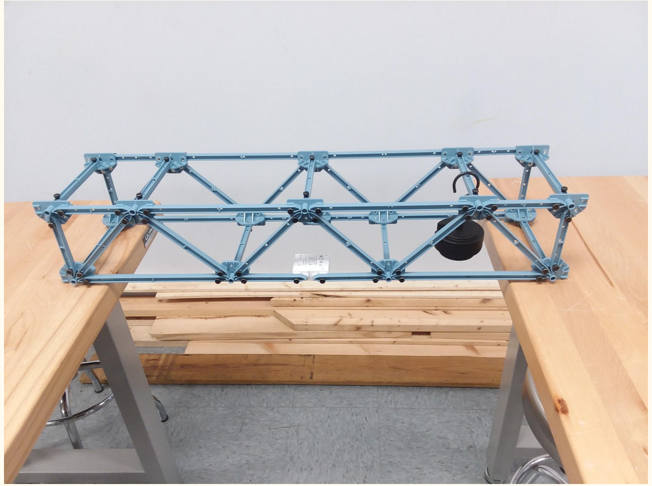

Fig 7 Shows the constructed Warren Truss

Procedure

- Structure was tested by using a weight and sensor. (see fig 9)
- Forces were recorded on the app at 3 different locations. (see fig 8)
- Once the model was tested, it was dis-assembled.

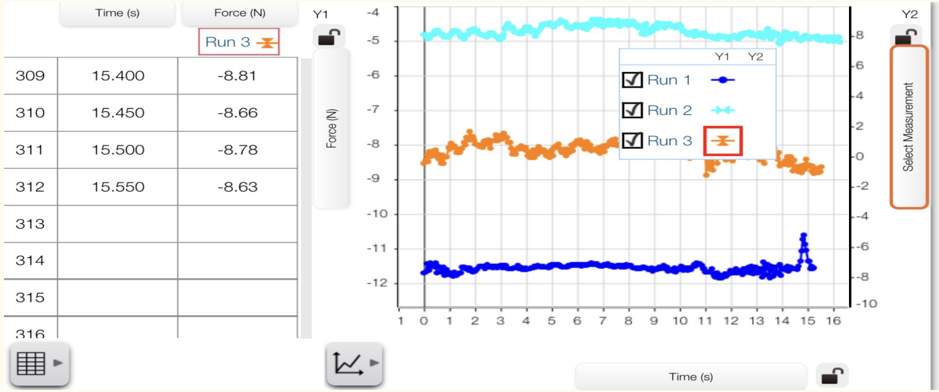

Fig 8 Shows the forces on the Pratt Truss during testing

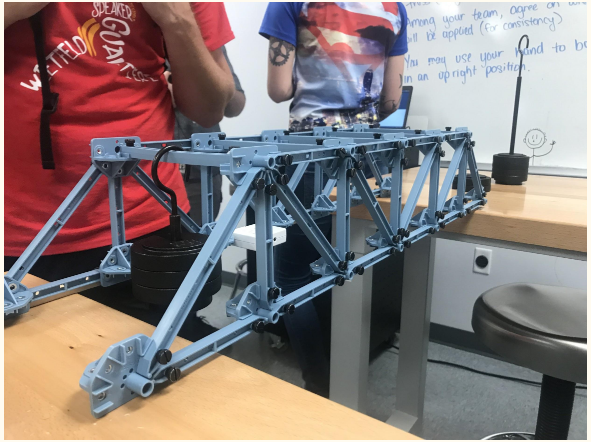

Fig 9 Shows constructed Pratt Truss

Bridge Designer Testing

Procedure

- Software: Bridge Designer 2016
- Use the Pratt Deck Truss bridge design as shown in fig 10.

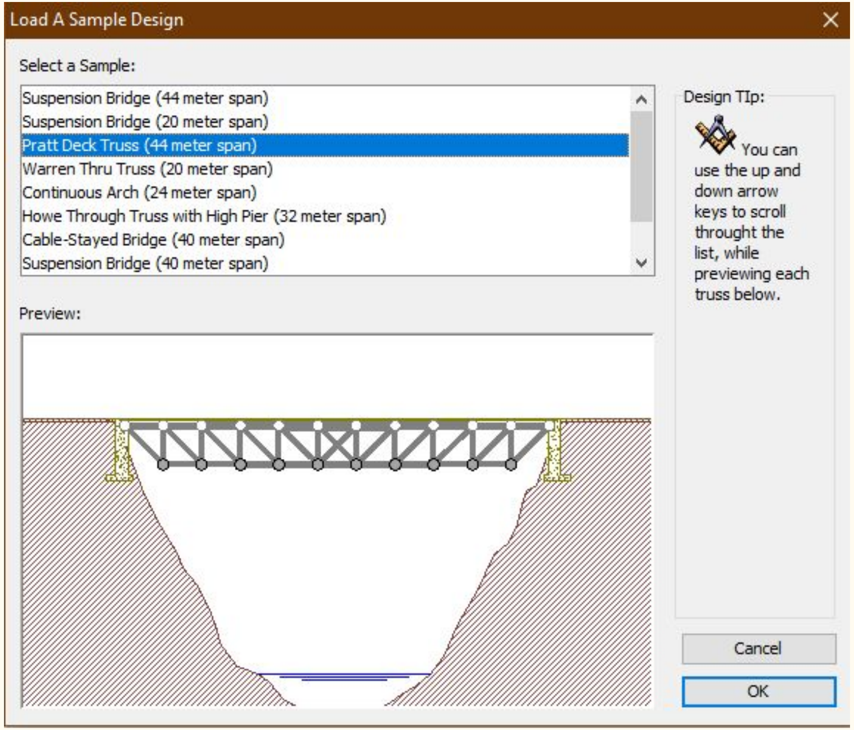

Fig 10 shows the example bridge used

Procedure

- Build specific truss type (see fig 11)

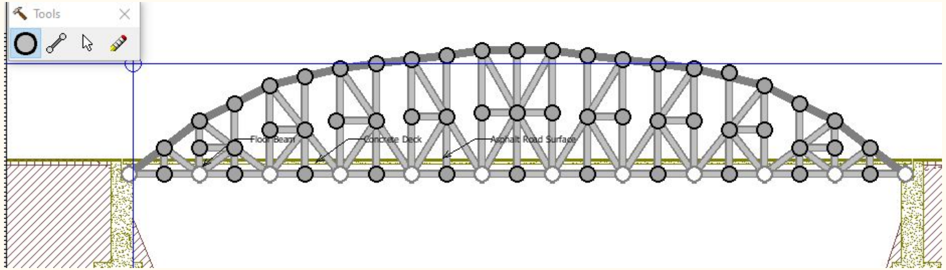

Fig 11 shows a pennsylvania truss

- Copy the test results to an excel sheet (see table 1 and 2)

#	Material Type	Cross Section	Size (mm)	Length (m)	Slender-ness	Compression Force/Strength	Tension Force/Strength
1	CS	Bar	160	2.00	43.30	0.00	0.36
2	CS	Bar	160	2.00	43.30	0.00	0.36
3	CS	Tube	160	1.50	24.14	0.00	0.00
4	CS	Tube	160	2.50	40.23	0.01	0.00
5	CS	Bar	160	2.00	43.30	0.00	0.35
6	CS	Bar	160	2.00	43.30	0.00	0.35
7	CS	Bar	160	2.00	43.30	0.00	0.38
8	CS	Bar	160	2.00	43.30	0.00	0.38
9	CS	Bar	160	2.00	43.30	0.00	0.43
10	CS	Bar	160	2.00	43.30	0.00	0.43
11	CS	Bar	160	2.00	43.30	0.00	0.45
12	CS	Bar	160	2.00	43.30	0.00	0.45
13	CS	Bar	160	2.00	43.30	0.00	0.45
14	CS	Bar	160	2.00	43.30	0.00	0.45
15	CS	Bar	160	2.00	43.30	0.00	0.44
16	CS	Bar	160	2.00	43.30	0.00	0.44
17	CS	Bar	160	2.00	43.30	0.00	0.39
18	CS	Bar	160	2.00	43.30	0.00	0.39

Table 2 shows some of the test results for a pennsylvania truss

Dennis H. Mahan Memorial Bridge
Project ID: 00001C-
Designed By: H08 - Group 7

#	Material Type	Cross Section	Size (mm)	Length (m)	Compression Force	Compression Strength	Compression Status	Tension Force	Tension Strength	Tension Status
1	CS	Solid Bar	110x110	6.4	0	465.22	OK	1421.05	2873.75	OK
2	CS	Solid Bar	110x110	6.4	0	465.22	OK	1137.17	2873.75	OK
3	CS	Solid Bar	90x90	6.4	0	208.48	OK	853.86	1923.75	OK
4	CS	Solid Bar	90x90	6.4	0	208.48	OK	573.97	1923.75	OK
5	CS	Solid Bar	90x90	6.4	12.38	208.48	OK	536.33	1923.75	OK
6	CS	Solid Bar	90x90	6.4	0	208.48	OK	816.22	1923.75	OK
7	CS	Solid Bar	110x110	6.4	0	465.22	OK	1099.53	2873.75	OK
8	CS	Solid Bar	110x110	6.4	0	465.22	OK	1383.41	2873.75	OK
9	CS	Hollow Tube	260x260x13	4	1914.86	2660.84	OK	0	3050.45	OK

Table 1 shows some of the excel data sheet for the Pratt truss

Procedure

- Calculate Force:Strength ratio in Columns H and L (see table 3)

F	G	H	I	J	K	L
Compression Force	Compression Strength	Ratio	Compression Status	Tension Force	Tension Strength	Ratio
0	465.22	0	OK	1421.05	2873.75	0.4944932579
0	465.22	0	OK	1137.17	2873.75	0.3957094389
0	208.48	0	OK	853.86	1923.75	0.4438518519

Table 3 shows the Force:Strength ratios of a Pratt truss

- Calculate Safety Factor using this equation in column N of table 4: `=IF(H5=0,IF(L5=0,0,1/L5),IF(L5=0,1/H5,IF(ABS(0.5-H5)>ABS(0.5-L5),1/H5,1/L5)))`

N
Safety Factor
2.022272263
2.527106765
2.253004005
3.35165601
16.84006462
2.356901326

Table 4 shows the Safety factor of a Pratt truss

Conclusion: Results and Discussion

The Pratt Truss was the best truss as supported by initial research and test results. It is stronger than the Warren Truss and ideal for the given length requirement. The Parker Truss would have been better for longer spans. The Pratt Truss was also one of the most cost effective designs.

The Warren Truss was overall effective with an average safety rating of 2.12, however, the bridge's cost at $422,947.21 put it at a disadvantage to the Pratt Truss.

Conclusion: Results and Discussion (cont.)

Although the software results for force:strength ratio and safety rating should have been closer to 0.5 and 2.0 respectively, the Pratt Truss was found to be the most cost-effective and stable truss design for the given parameters. Both strength, safety, and cost requirements were met, values could have been closer to the above stated ideals.

- Average Compression Force:Strength ratio: 0.347
- Average Tension Force:Strength ration: 0.208
- Average Compression Safety Factor: 2.879
- Average Tension Safety Factor: 4.810
- Average Overall Safety Factor: 3.167
- Cost: $314,947.28

Future Work

Additional research could include adding piers and pier abutments to the truss designs. While this may add to the overall cost, it could shed light on alternative truss designs made impractical due to excessive tensile or compressive forces.

Different softwares could even be used to test the reliability of algorithms. Additionally, truss designs not within the scope of this research should also be tested.

Real world applications include constructions of bridges and industrial complexes.

Any Questions?

References

Abbett, Robert W. (1957). American Civil Engineering Practice. III. New York: John Wiley & Sons. pp. 26–22&26–32.

Adeli, H., and K. V. Balasubramanyam. "A knowledge-based system for design of bridge trusses." Journal of Computing in Civil Engineering 2.1 (1988): 1-20.

Boon, Garrett. “Pratt Truss Bridge.” Garrett's Bridges, 11 Jan. 2011, https://www.garrettsbridges.com/design/pratt-truss/

Bridge Basics - A Spotter's Guide to Bridge Design, pghbridges.com/basics.htm.

Cadena, Richard. Automated Lighting: The Art and Science of Moving Light in Theatre, Live Performance and Entertainment. Routledge, 2013

Chilton, John. Space grid structures. Routledge, 2007

Christie, Huntly Gordon, and Percy Adler. "Truss assembly and method of constructing a truss structure." U.S. Patent No. 9,909,299. 6 Mar. 2018.

Gasparini, D. A., and Caterina Provost. “Early Nineteenth Century Developments in Truss Design in Britain, France and the United States.” Construction History, vol. 5, 1989, pp. 21–28. JSTOR, www.jstor.org/stable/41613663.

"Glossary - "Abutment"". U.S. Bureau of Reclamation. Retrieved 24 January 2015

References (cont.)

Greismer, Fanny. “Modeling a Pratt Truss Bridge.” COMSOL Multiphysics, 28 Dec. 2012, https://www.comsol.com/blogs/modeling-a-pratt-truss-bridge/.

Griggs, Frank. “The Warren Truss.” STRUCTURE Magazine, STRUCTURE, July 2015, https://www.structuremag.org/?p=8715.

Guise, David. “The Evolution of the Warren, or Triangular, Truss.” IA. The Journal of the Society for Industrial Archeology, vol. 32, no. 2, 2006, pp. 23–34. JSTOR, www.jstor.org/stable/40968737.

Fig. 1. Herbudiman, B., et al. “Design of Pedestrian Truss Bridge with Sengon-Rubber Laminated Veneer Lumber.” IOP Conference Series: Earth and Environmental Science, vol. 109, Dec. 2017, pp. 1–10, doi:10.1088/1755-1315/109/1/012029.

Historic Bridge Patents, http://historicbridges.org/info/patents/

“History of a Truss Bridge.” Tennessee State Government - TN.gov, https://www.tn.gov/tdot/structures-/historic-bridges/history-of-a-truss-bridge.html.

National Register of Historic Places Registration Form for Healdsburg Memorial Bridge, California State Park System, accessed 2011-12-26.

“NCDOT.” NCDOT, www.ncdot.gov/initiatives-policies/Transportation/bridges/historic-bridges/bridge-types/ Pages/truss.aspx.

“Pratt Truss Bridge.” Pratt Truss - Bridge Design by Thomas and Caleb Pratt, http://www.historyofbridges.com/facts-about-bridges/pratt-truss/

References (cont.)

Rusinkiewicz, Prof. Szymon. “The Pratt Truss Bridge.” Princeton University, The Trustees of Princeton University, https://www.cs.princeton.edu/courses/archive/fall09/cos323/assign/truss/truss.html.

“Truss Bridge Plan.” Pennsylvania Department of Transportation, www.penndot.gov/ProjectAndPrograms/Cultural%20Resources/Pages/Truss-Bridge-Plan .aspx.

Waddell, J. A. L. Bridge Engineering. Vol. 1, National Academy of Sciences, Transportation Research Board, 1978

Urquhart, Leonard Church (1959). Civil Engineering Handbook (4th ed.). New York: McGraw-Hill Book Company. pp. 8–75.

Yap, Alyssa. “Project 1: Fettucine Truss Bridge.” LinkedIn SlideShare, 7 July 2015, https://www.slideshare.net/alyssa1994/project-1-fettucine-truss-bridge

Yogish, C. B. “The Structural Reliability Assessment of Pratt Truss with Post-Tensioning for Strengthening and Rehabilitation.” IRJET, 4 April 2017, https://pdfs.semanticscholar.org/4360/2acea4477cd547e41e410ea62cc82fecaf81.pdf.