March 31, 2016

Kevin R. Kline, PE, District Executive
PennDOT Engineering District 2-0
1924 Daisy Street - P.O. Box 342
Clearfield County, PA 16830

Dear Mr. Kline:

Reference. PennDOT Engineering District 2-0, Statement of Work, subj: Concept Design for Vehicle Bridge over Spring Creek along Puddintown Road in College Township, Centre County, PA, dated September 11, 2015.

***Statement of Problem.** All traffic must now be re-routed more than 10 miles around the destroyed bridge, thereby causing us to find a way to make a new bridge that prevents corrosion from lessening the bridges efficiency.

Objective. Pennsylvania Department of Transportation of (PennDOT) Engineering District 2-0 has initiated an emergency, fast-track project to replace the destroyed bridge using either the Howe or the Warren bridge.

Design Criteria. PennDOT District 2-0 has established the design criteria for the replacement bridge to include: All other design criteria, such as: steel member type, steel cross section type, and steel member.

Technical Approach.

Phase 1: Economic Efficiency.

Using Engineering Encounters Bridge Design 2015 (EEBD 2015) a bridge design was optimized to ensure a cost efficient and stable design using this system of estimation.

Phase 2: Structural Efficiency.

To test the structural efficiency, we will test a Popsicle stick model bridge to decide the efficiency of our two bridges.

Results.

Phase 1: Economic Efficiency.

As seen in Attachment 1 both bridges were designed to take full advantage of the materials used making sure both designs costs are as efficient as possible.

Phase 2: Structural Efficiency. various methods were used to optimize the materials assuring safety and stability creating a design that is able to with hold the required weight.

Best Solution.

(i) The Economic Efficiency ($207,502.56) of our design team's Howe through truss bridge versus the economic efficiency ($195,803.83) of our design teams Warren through truss bridge as shown in Tables Nos. 1 and 4 respectively, show that the Warren bridge was made slightly better suited for the job.

(ii) The Structural Efficiency Comparing both the Howe Truss bridge and the Warren Truss bridge with the other teams bridges the Warren truss bridge is clearly more structurally efficient (SE=460).

(iii) The Design Efficiency, Based on, the total cost ($207,502.56) of the Howe truss bridge divided by the Structural Efficiency (260) of the Howe truss bridge (as $207,502.56/260) versus the total cost ($195,803.83) of the Warren truss bridge divided by the Structural Efficiency (420) of the Warren truss (as $195,803.83/420). The owe truss bridge is the better solution since it had a higher score of 798.

(iv) Because of the amount held within the bridge test as well as the Cost of each bridge, the Warren bridge was shown to be more efficient in both ways as it held more and was cheaper than the Howe Truss bridge. The cost comparison can be seen on tables1.2 as well as 2.2 for comparison.

Conclusions and Recommendations. In conclusion, The better bridge for this project would be the Warren bridge. To forward the project towards completing the method of building it would be using quenched and tempered steel tubes.

Respectfully,

Bailey Frisco <Design Team Member #1>
Engineering Student
EDSGN100 Section 001
Design Team 2
Steel Corps.
College of Engineering
Penn State University

Isaiah Wright <Design Team Member #2>
Engineering Student
EDSGN100 Section 001
Design Team 2
Steel Corps.
College of Engineering
Penn State University

Nelson DiBiase
<Design Team Member #3>
Engineering Student
EDSGN100 Section 001
Design Team 2

Youseif Alotaibi
<Design Team Member #4>
Engineering Student
EDSGN100 Section 001
Design Team 2

Steel Corps.
College of Engineering
Penn State University

ATTACHMENT 1

Phase 1: Economic Efficiency

Howe Truss.

Using Bridge Designer 2016 as a tool to measure the efficiency of both the cost and strength of the bridge a design was created to optimize the usage of every member creating a very stable efficient bridge with a minimum cost of $207,500 saving $67,500 from the main budget please refer to table 2 page 9. Using the strongest but highest costing material (Quenched and tempered steel) hollow tubes were the most efficient materiel to work with. Each member was pushed to the limits however with safety precautions in mind creating a very stable efficient usage of bridge please refer to table 1 page 8. Both members number 23 and 37 hold the highest ratio. Member number 23 holding the highest ratio in tension and member 37 holding the highest ratio in compression as you can see below.

23	QTS	Tube	90	8.94	254.48	0.00	0.99
37	QTS	Tube	200	5.66	72.83	0.99	0.00

Warren Truss.

Using the experience gained from the Howe bridge design, Bridge Designer 2016 was used as a tool to measure the efficiency of both the cost and strength of the bridge a design was created to optimize the usage of every member creating a very stable efficient bridge with a minimum cost of $195,800 saving $79,200 from the main budget please refer to table 5 page 12. Using the strongest but highest costing material (Quenched and tempered steel) hollow tubes were most efficient materiel to work with. Each member was pushed to the limits however with safety precautions in mind creating a very stable efficient usage of bridge please refer to table 1 page 8. Both members number 10, 11, and 19 hold the highest ratio. Members number 10 and 11 holding the highest ratio in tension and member 19 holding the highest ratio in compression as you can see below.

10	QTS	Tube	150	4.00	68.44	0.00	0.99
11	QTS	Tube	150	4.00	68.44	0.00	0.99
19	QTS	Tube	180	4.00	57.22	0.99	0.00

ATTACHMENT 2

Phase 2: Structural Efficiency

Howe Truss.

Prototype Bridge. The method towards this almost master piece was to have the bottom cord and top supporting the inner verticals as well as the hip verticals to help strengthen the bridges output of strength. The bridge took the full 60 Popsicle sticks for its creation.

Load Testing. In comparison to the other design teams, our Howe Truss was not as Structurally Efficient. Our bridge fell into the middle on SE when compared to the other bridges. The minimum SE was less than 200, as seen in Figure 7, and the maximum was over 600 where as ours was approximately 260.

Forensic Analysis. The Howe bridge had a few minor mistakes that caused its demise but not complete demise. The reason for its failure was for the vertical connecting the bottom cord 9,and 10. It failed by these parts blowing apart not being able to support the bottom cord enough. The reason i said not complete demise as seen within the Warren bridge as well is because it didn't shatter but one piece disconnected.

Results. please refer to figure 7

Warren Truss.

Prototype Bridge. The design concept was to focus mainly on the the framing of the verticals creating a solid strong support then adding the verticals to assure maximum optimization of the bridge. after the two sides were made 8 Popsicles were used to bond and connect the two side, 4 on connected the bottom cords and the other 4 connected the top cords. Every Popsicle was used wasting no material.

Load Testing. In comparison to the other design teams, our Warren Truss was Structurally Efficient. The bridge had the second highest SE when compared to the other bridges. The minimum SE was about 190, as seen in Figure 8, and the maximum was over 600 where as ours was approximately 420.

Forensic Analysis. The design proved to be very efficient but had few details that need to be modified. The bridge believed to fail as a result of the spacing between the cords which framed the verticals creating an undistributed division of weight which ended in a disasters failure.

Results. please refer to figure 8

TABLES

						Load Test Results	
#	Material Type	Cross Section	Size (mm)	Length (m)	Slender-ness	Compression Force/Strength	Tension Force/Strength
1	QTS	Tube	140	4.00	73.57	0.00	0.81
2	QTS	Tube	160	4.00	64.37	0.00	0.88
3	QTS	Tube	170	4.00	60.41	0.00	0.90
4	QTS	Tube	170	4.00	60.41	0.00	0.88
5	QTS	Tube	160	4.00	64.37	0.00	0.85
6	QTS	Tube	160	4.00	64.37	0.00	0.85
7	QTS	Tube	170	4.00	60.41	0.00	0.87
8	QTS	Tube	170	4.00	60.41	0.00	0.89
9	QTS	Tube	160	4.00	64.37	0.00	0.85
10	QTS	Tube	130	4.00	78.92	0.00	0.98
11	QTS	Tube	220	5.66	66.21	0.76	0.00
12	QTS	Tube	140	4.00	73.57	0.00	0.60
13	QTS	Tube	170	4.12	62.27	0.94	0.00
14	QTS	Tube	180	6.40	91.59	0.89	0.00
15	QTS	Tube	120	5.00	107.29	0.00	0.50
16	QTS	Tube	190	4.12	55.73	0.98	0.00
17	QTS	Tube	160	7.21	116.05	0.85	0.00
18	QTS	Tube	90	6.00	170.71	0.00	0.51
19	QTS	Tube	200	4.12	53.08	0.89	0.00
20	QTS	Tube	120	8.06	172.99	0.81	0.27
21	QTS	Tube	140	7.00	128.74	0.75	0.05
22	QTS	Tube	200	4.12	53.08	0.87	0.00
23	QTS	Tube	90	8.94	254.48	0.00	0.99
24	QTS	Tube	90	8.00	227.61	0.00	0.98
25	QTS	Tube	100	8.94	230.30	0.00	0.79
26	QTS	Tube	200	4.12	53.08	0.86	0.00
27	QTS	Tube	140	7.00	128.74	0.92	0.04
28	QTS	Tube	120	8.06	172.99	0.69	0.34
29	QTS	Tube	200	4.12	53.08	0.88	0.00
30	QTS	Tube	90	6.00	170.71	0.76	0.49
31	QTS	Tube	160	7.21	116.05	0.81	0.03
32	QTS	Tube	190	4.12	55.73	0.95	0.00
33	QTS	Tube	90	5.00	142.26	0.00	0.96
34	QTS	Tube	180	6.40	91.59	0.86	0.00
35	QTS	Tube	170	4.12	62.27	0.91	0.00
36	QTS	Tube	120	4.00	85.83	0.00	0.80
37	QTS	Tube	200	5.66	72.83	0.99	0.00

Table 1.1 Howe Truss Bridge

Type of Cost	Item	Cost Calculation	Cost
Material Cost (M)	Quenched & Tempered Steel Hollow Tube	(6695.0 kg) x ($7.70 per kg) x (2 Trusses) =	$103,102.56
Connection Cost (C)		(20 Joints) x (400.0 per joint) x (2 Trusses) =	$16,000.00
Product Cost (P)	5 - 90x90x4 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	1 - 100x100x5 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	4 - 120x120x6 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	1 - 130x130x6 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	4 - 140x140x7 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	6 - 160x160x8 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	6 - 170x170x8 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	2 - 180x180x9 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	2 - 190x190x9 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	5 - 200x200x10 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	1 - 220x220x11 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
Site Cost (S)	Deck Cost	(10 4-meter panels) x ($4,700.00 per panel) =	$47,000.00
	Excavation Cost	(19,400 cubic meters) x ($1.00 per cubic meter) =	$19,400.00
	Abutment Cost	(2 standard abutments) x ($5,500.00 per abutment) =	$11,000.00
	Pier Cost	No pier =	$0.00
	Cable Anchorage Cost	No anchorages =	$0.00
Total Cost	**M + C + P + S**	**$103,102.56 + $16,000.00 + $11,000.00 + $77,400.00 =**	**$207,502.56**

Table 1.2 Howe Truss bridge

Current Material

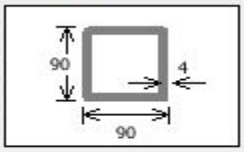
Material Properties:

Material	Quenched & Tempered Steel
Yield Stress (Fy)	485000 kN per sq. meter
Modulus of Elasticity (E)	2.00E+08 kN per sq. meter
Mass Density	7850 kg per cubic meter

Dimensions:

Cross-Section Type	Hollow Tube
Cross-Section Size	90x90x4
Area	0.0014 sq. meters
Moment of Inertia	1.70E-06 meters^4
Member Length	--

Section (mm):



Cost:

Unit Cost	$83.17 per meter
Member Cost	--

Strength vs. Length: Graph all tabs Member:

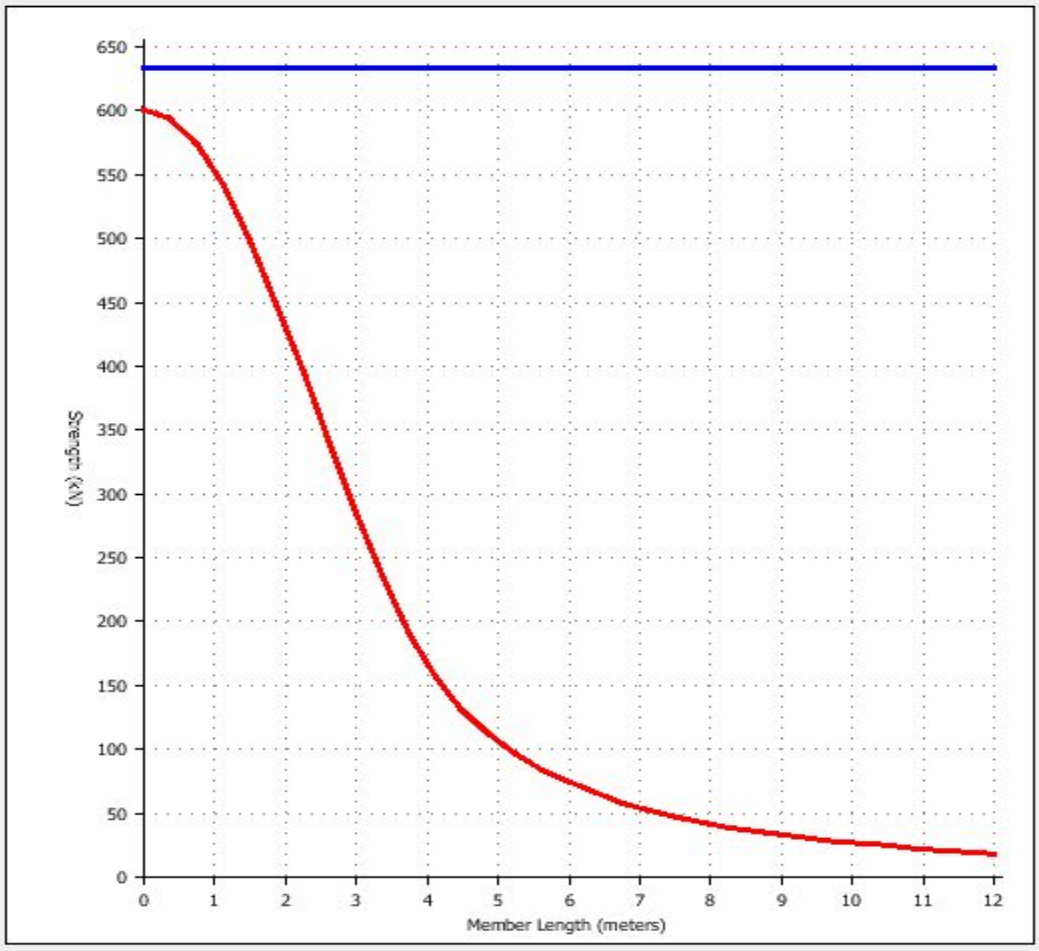


Table 1.3 Howe Truss Bridge

Load Test Results							
#	Material Type	Cross Section	Size (mm)	Length (m)	Slender-ness	Compression Force/Strength	Tension Force/Strength
1	QTS	Tube	180	4.47	63.97	0.87	0.00
2	QTS	Tube	120	4.47	95.96	0.00	0.95
3	QTS	Tube	160	4.12	66.35	0.93	0.00
4	QTS	Tube	160	5.39	86.66	0.91	0.00
5	QTS	Tube	100	5.39	138.66	0.00	0.83
6	QTS	Tube	100	4.00	102.99	0.00	0.79
7	QTS	Tube	140	4.00	73.57	0.00	0.88
8	QTS	Tube	160	4.00	64.37	0.00	0.83
9	QTS	Tube	160	4.00	64.37	0.00	0.86
10	QTS	Tube	150	4.00	68.44	0.00	0.99
11	QTS	Tube	150	4.00	68.44	0.00	0.99
12	QTS	Tube	160	4.00	64.37	0.00	0.86
13	QTS	Tube	160	4.00	64.37	0.00	0.83
14	QTS	Tube	140	4.00	73.57	0.00	0.87
15	QTS	Tube	100	4.00	102.99	0.00	0.77
16	QTS	Tube	180	4.12	58.98	0.97	0.00
17	QTS	Tube	190	4.12	55.73	0.98	0.00
18	QTS	Tube	190	4.12	55.73	0.97	0.00
19	QTS	Tube	180	4.00	57.22	0.99	0.00
20	QTS	Tube	190	4.12	55.73	0.97	0.00
21	QTS	Tube	190	4.12	55.73	0.97	0.00
22	QTS	Tube	180	4.12	58.98	0.95	0.00
23	QTS	Tube	160	4.12	66.35	0.91	0.00
24	QTS	Tube	150	6.32	108.21	0.87	0.00
25	QTS	Tube	75	6.32	214.98	0.00	0.98
26	QTS	Tube	120	7.28	156.21	0.85	0.21
27	QTS	Tube	140	7.28	133.89	0.74	0.07
28	QTS	Tube	90	8.25	234.62	0.00	0.85
29	QTS	Tube	110	8.25	192.15	0.78	0.37
30	QTS	Tube	120	8.25	176.94	0.75	0.26
31	QTS	Tube	90	8.25	234.62	0.00	0.94
32	QTS	Tube	140	7.28	133.89	0.92	0.06
33	QTS	Tube	120	7.28	156.21	0.75	0.27
34	QTS	Tube	75	6.32	214.98	0.64	0.94
35	QTS	Tube	150	6.32	108.21	0.83	0.01
36	QTS	Tube	100	5.39	138.66	0.00	0.81
37	QTS	Tube	160	5.39	86.66	0.88	0.00
38	QTS	Tube	130	4.47	88.24	0.00	0.85
39	QTS	Tube	180	4.47	63.97	0.85	0.00

Table 2.1 Warren Truss Bridge

Type of Cost	Item	Cost Calculation	Cost
Material Cost (M)	Quenched & Tempered Steel Hollow Tube	(5883.4 kg) x ($7.70 per kg) x (2 Trusses) =	$90,603.83
Connection Cost (C)		(21 Joints) x (400.0 per joint) x (2 Trusses) =	$16,800.00
Product Cost (P)	2 - 75x75x3 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	2 - 90x90x4 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	4 - 100x100x5 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	1 - 110x110x5 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	4 - 120x120x6 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	1 - 130x130x6 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	4 - 140x140x7 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	4 - 150x150x7 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	8 - 160x160x8 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	5 - 180x180x9 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
	4 - 190x190x9 mm Quenched & Tempered Steel Tube	($1,000.00 per Product) =	$1,000.00
Site Cost (S)	Deck Cost	(10 4-meter panels) x ($4,700.00 per panel) =	$47,000.00
	Excavation Cost	(19,400 cubic meters) x ($1.00 per cubic meter) =	$19,400.00
	Abutment Cost	(2 standard abutments) x ($5,500.00 per abutment) =	$11,000.00
	Pier Cost	No pier =	$0.00
	Cable Anchorage Cost	No anchorages =	$0.00
Total Cost	**M + C + P + S**	**$90,603.83 + $16,800.00 + $11,000.00 + $77,400.00 =**	**$195,803.83**

Table 2.2 Warren Truss Bridge

Current Material

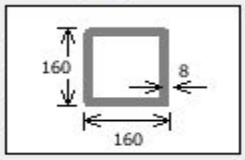
Material Properties:

Material	Quenched & Tempered Steel
Yield Stress (Fy)	485000 kN per sq. meter
Modulus of Elasticity (E)	2.00E+08 kN per sq. meter
Mass Density	7850 kg per cubic meter

Dimensions:

Cross-Section Type	Hollow Tube
Cross-Section Size	160x160x8
Area	0.0049 sq. meters
Moment of Inertia	1.88E-05 meters^4
Member Length	--

Section (mm):



Cost:

Unit Cost	$294.00 per meter
Member Cost	--

Strength vs. Length: Graph all tabs Member:

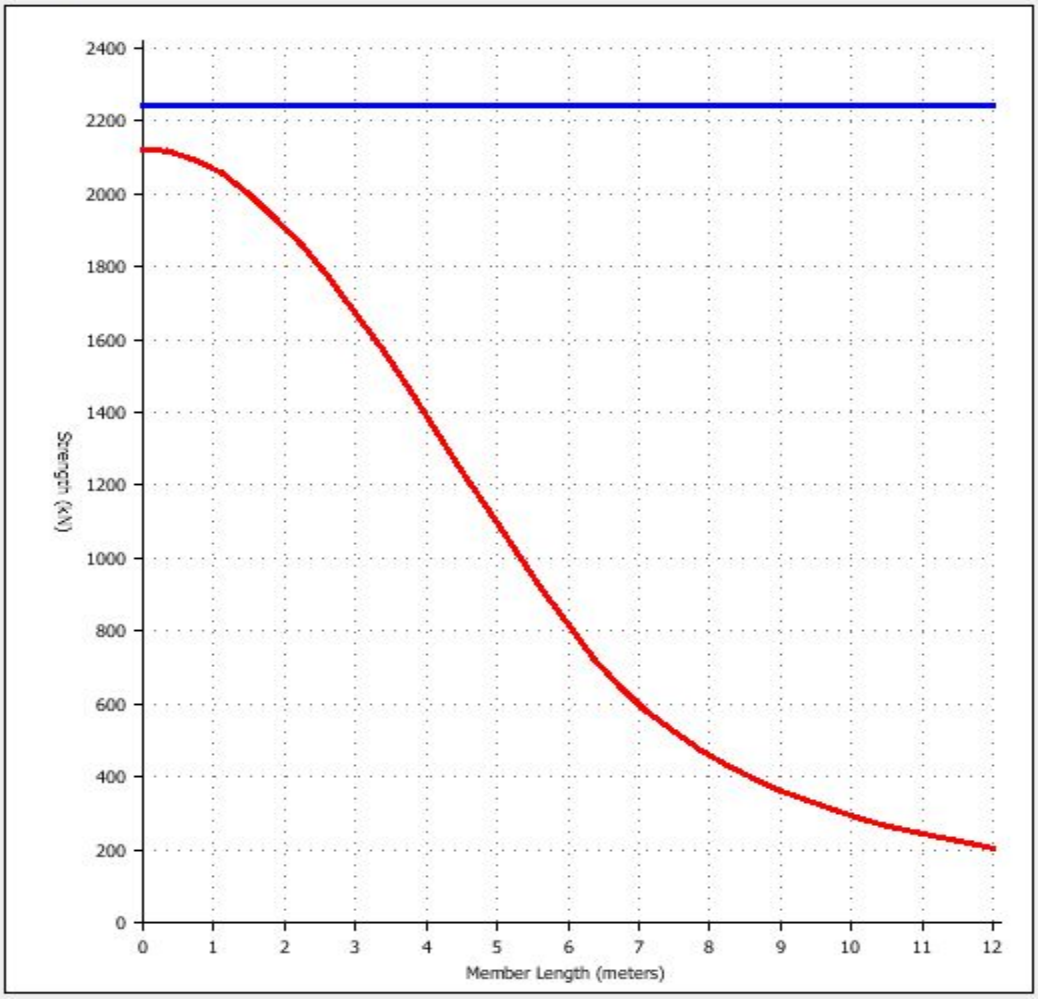


Table 2.3 Warren Truss Bridge

FIGURES

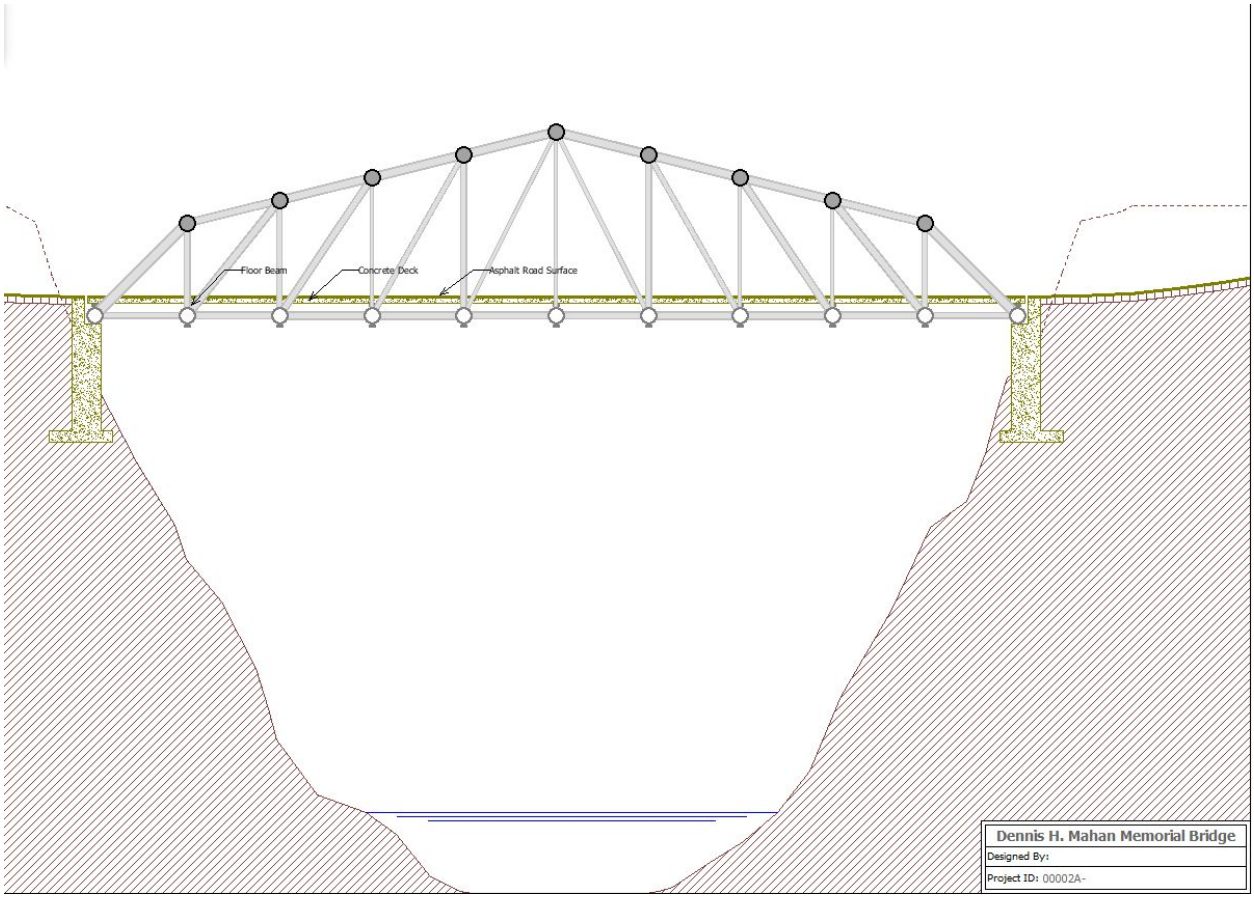

Floor Beam
Concrete Deck
Asphalt Road Surface
Dennis H. Mahan Memorial Bridge
Designed By:
Project ID: 00002A-

Figure 1

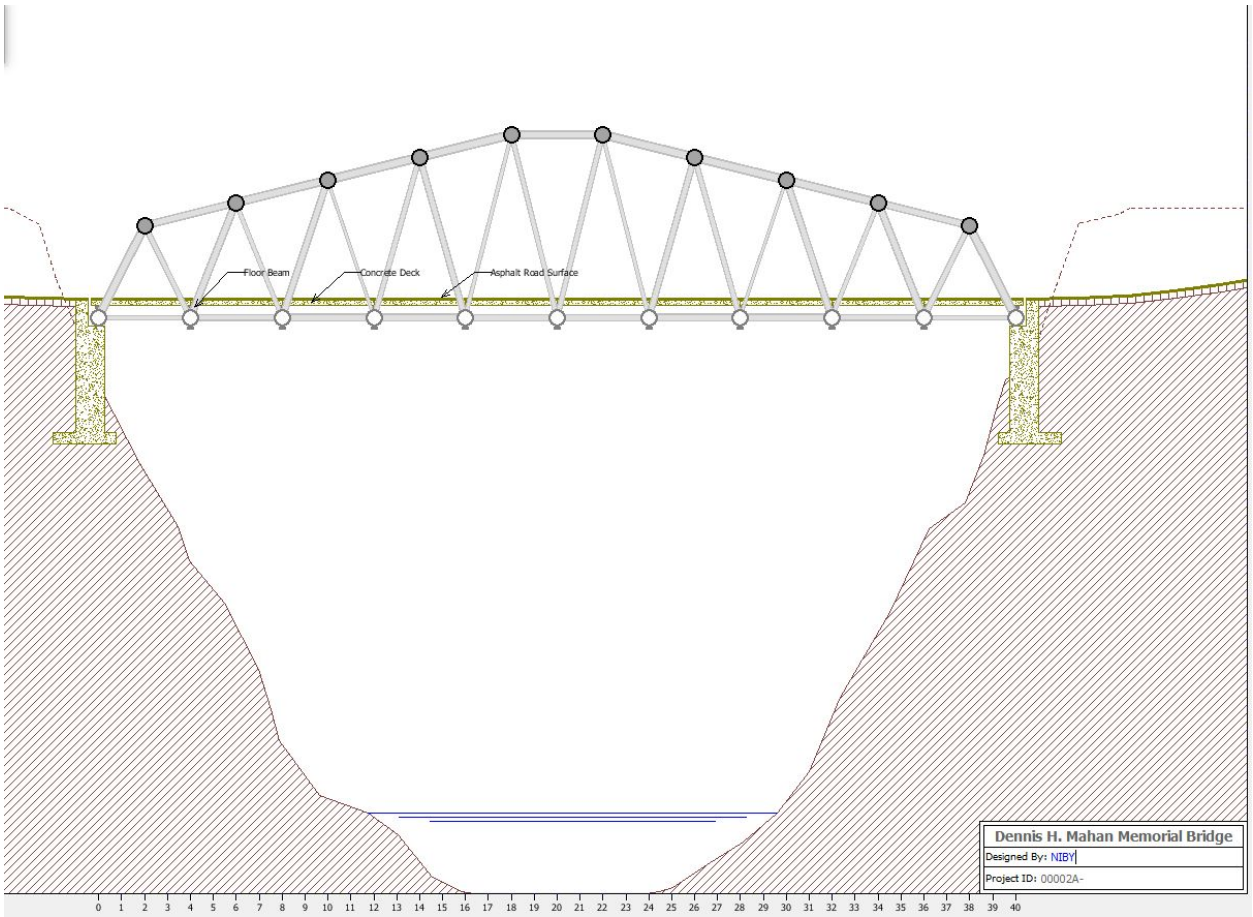

Floor Beam
Concrete Deck
Asphalt Road Surface
Dennis H. Mahan Memorial Bridge
Designed By: NIBY
Project ID: 00002A-
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

Figure 2

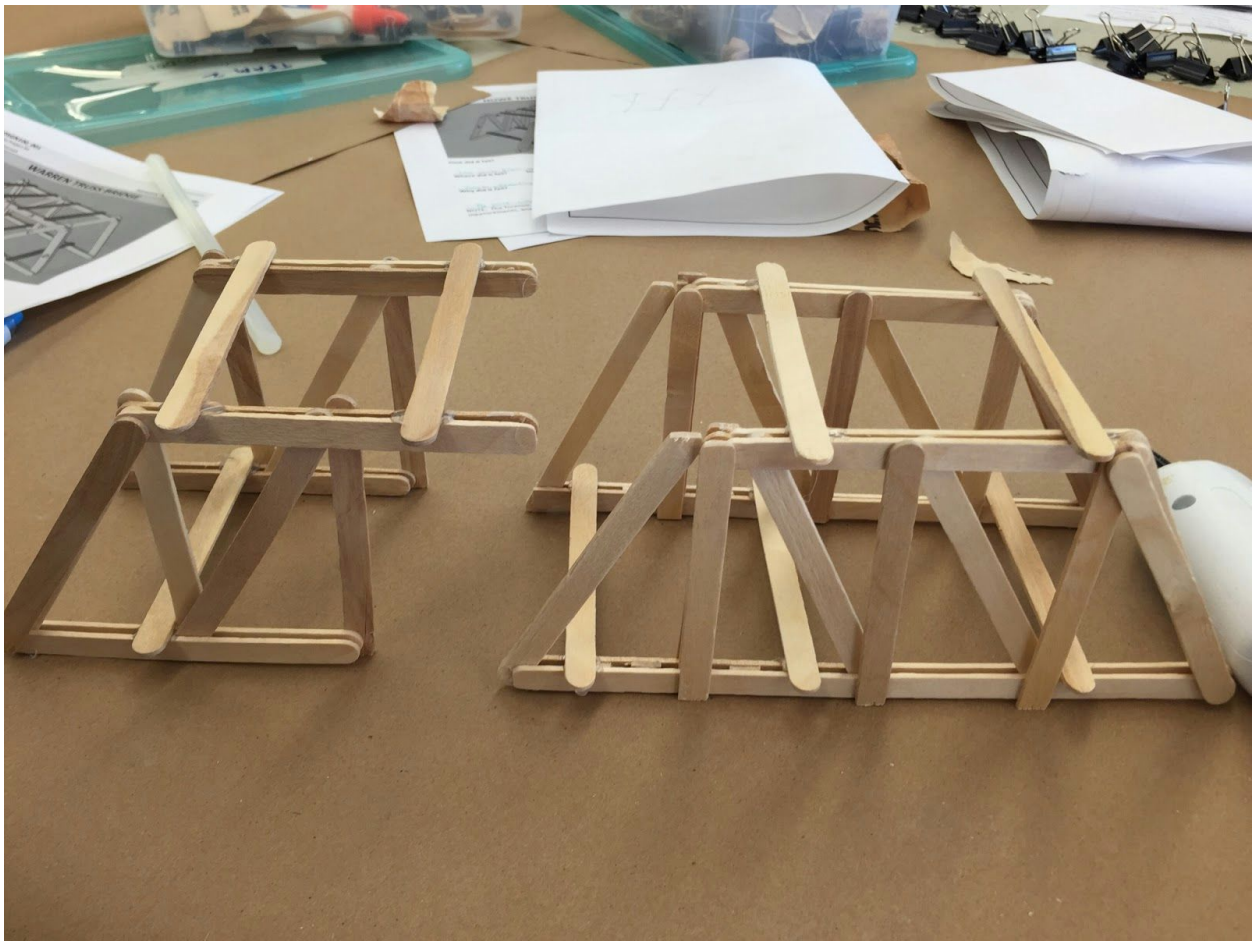


Figure 3

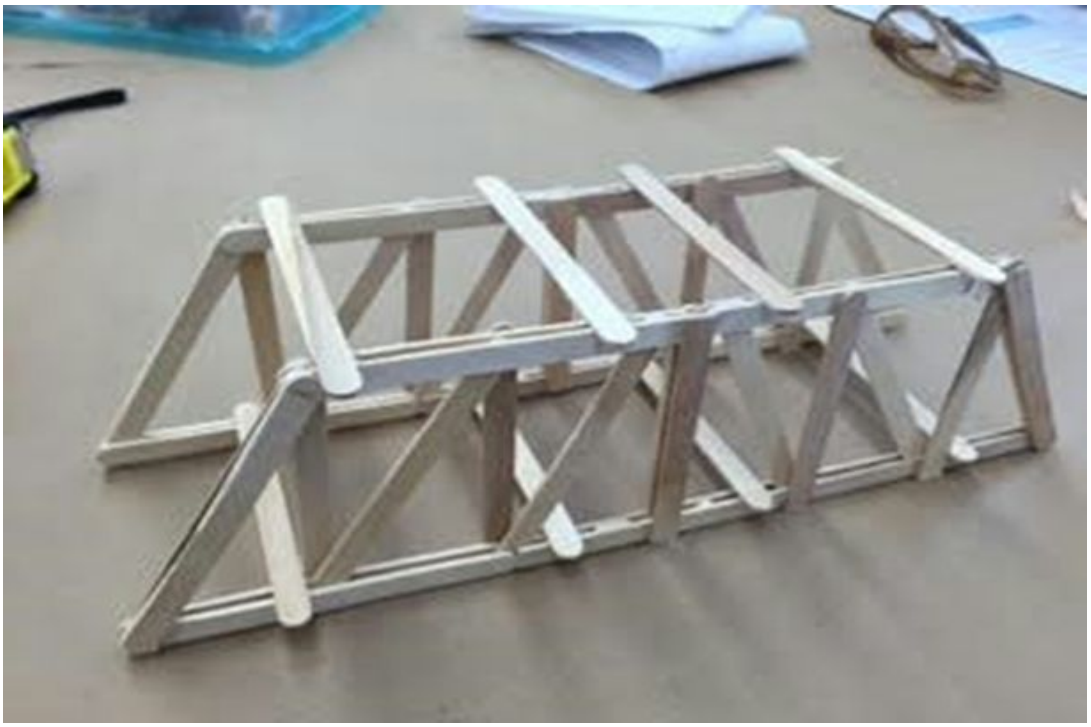


Figure 4

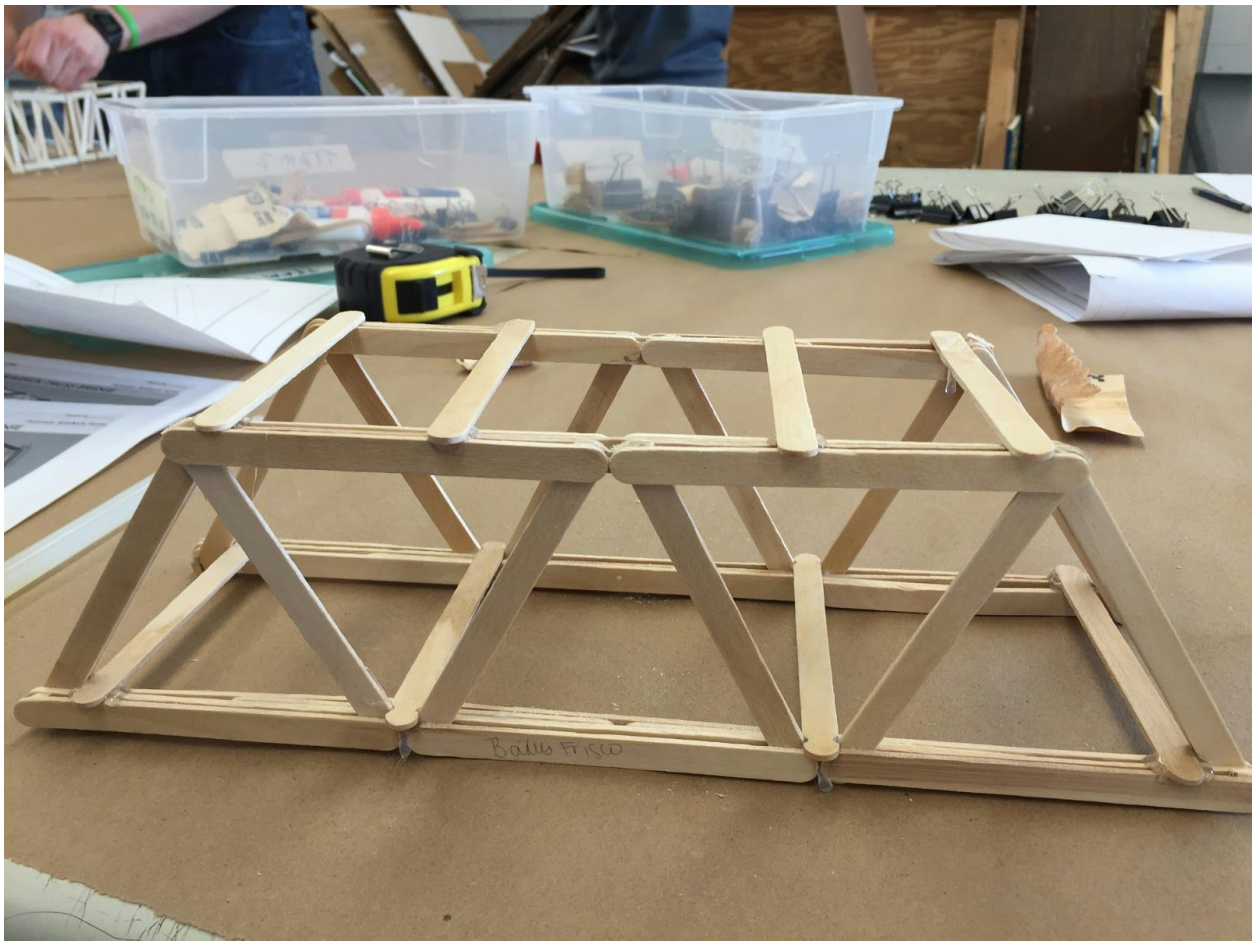


Figure 5

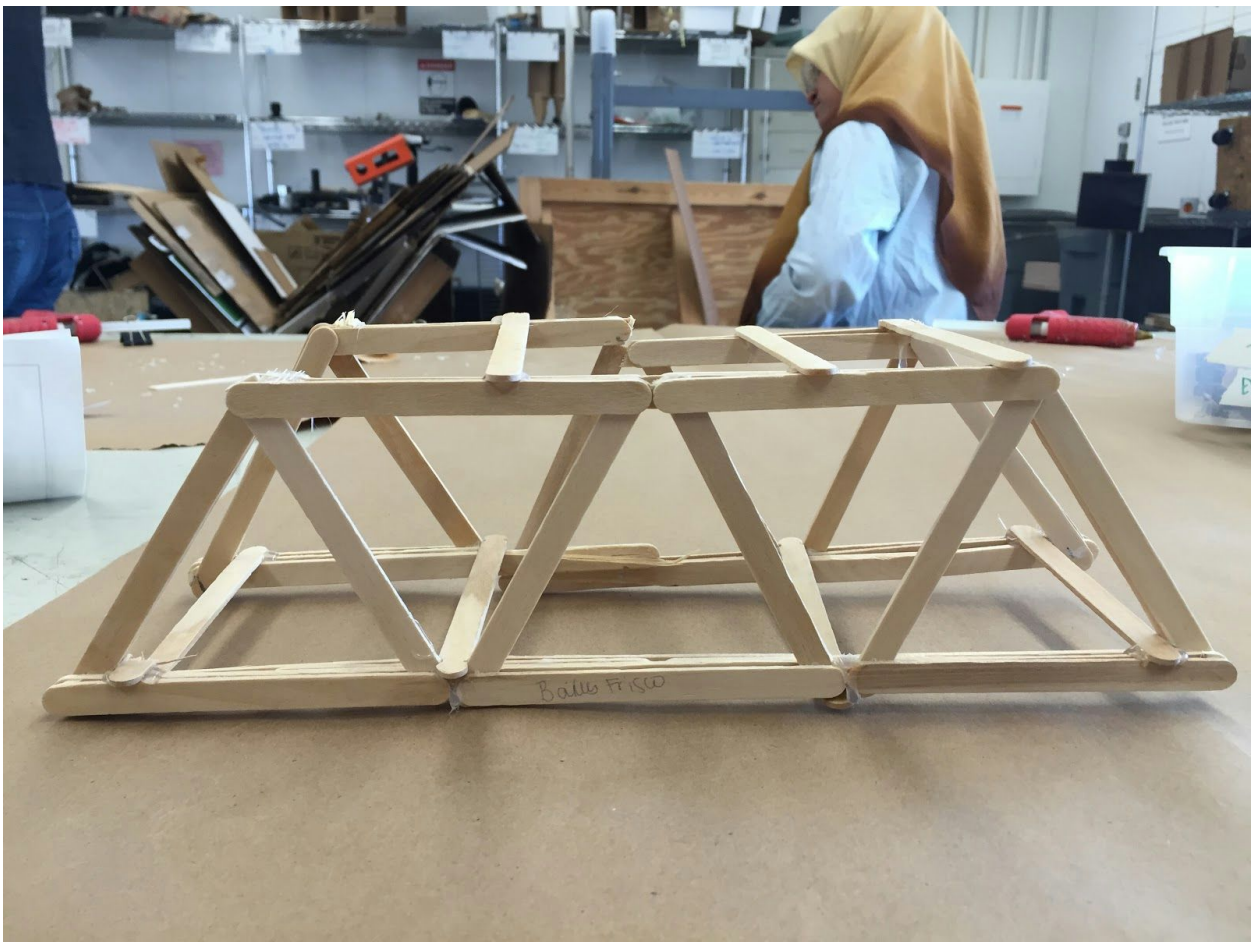


Figure 6

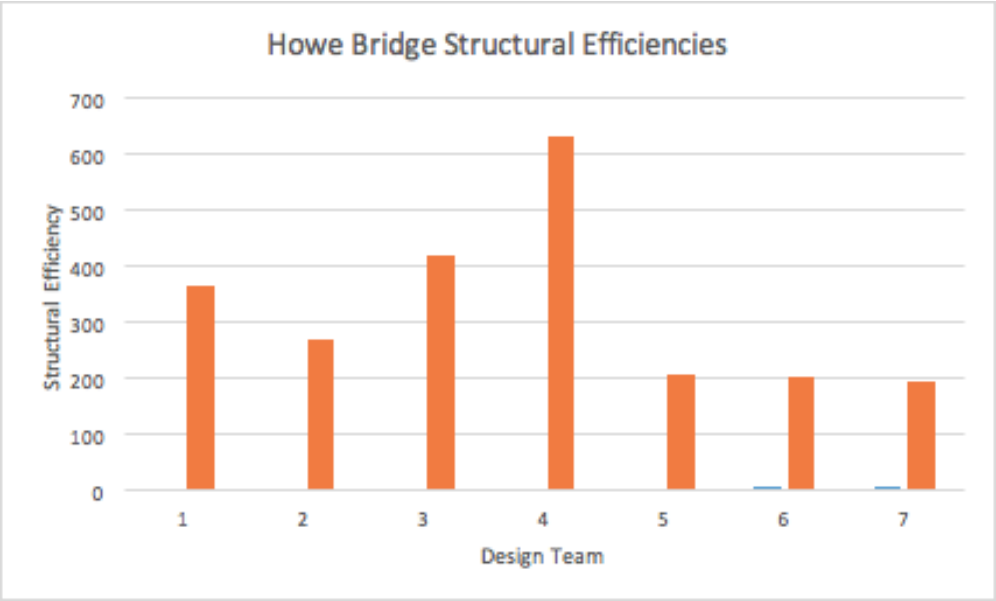

Howe Bridge Structural Efficiencies
Structural Efficiency
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
Design Team

Figure 7

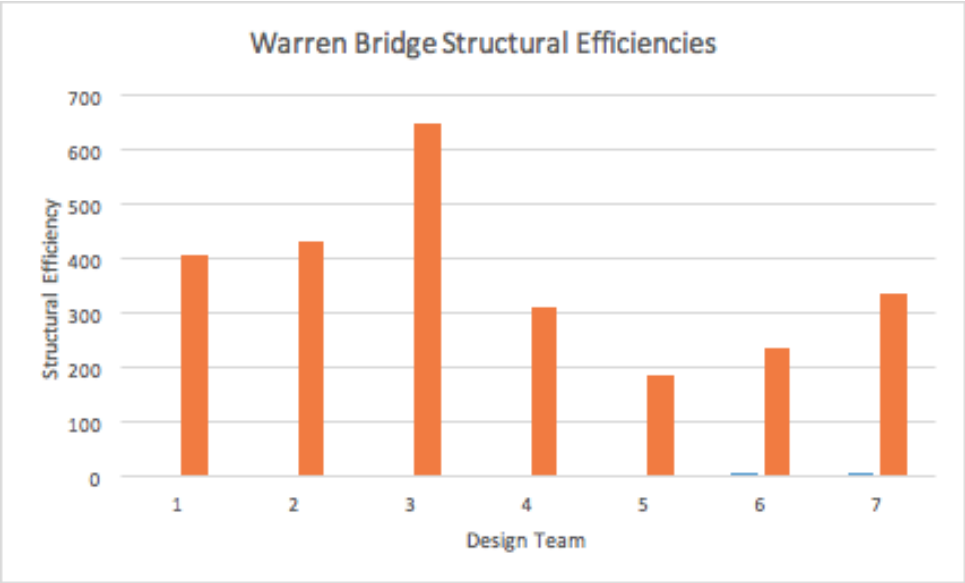

Warren Bridge Structural Efficiencies
Structural Efficiency
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
Design Team

Figure 8