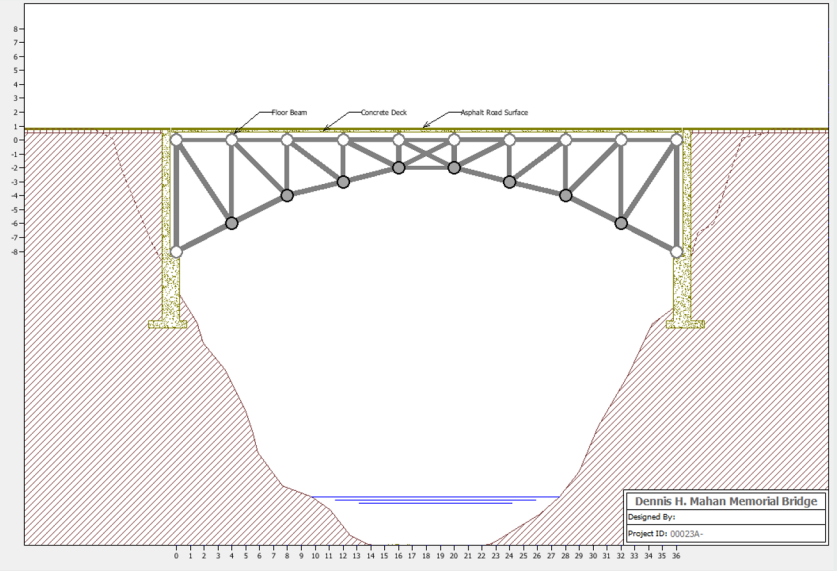
West Point Bridge Design

B.M.C. Durfee High School
Principles of Engineering
13 January, 2020



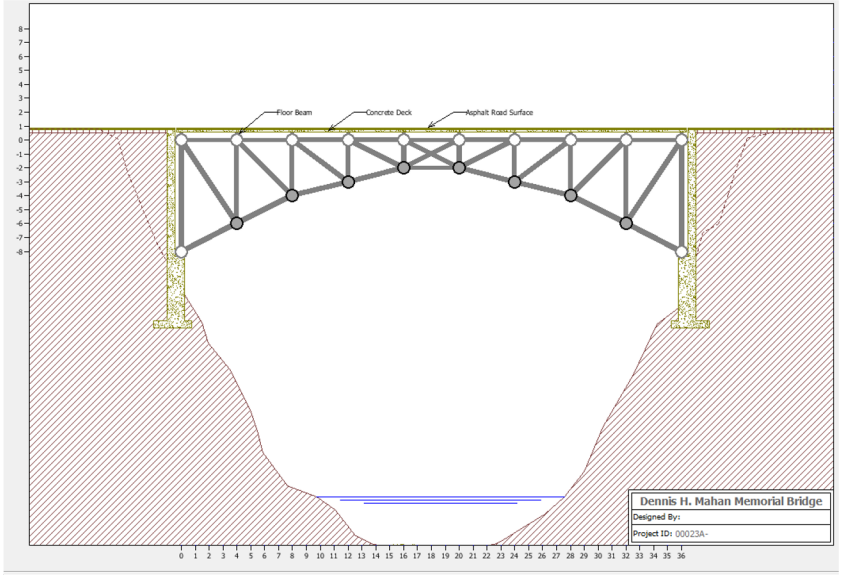
Design Brief

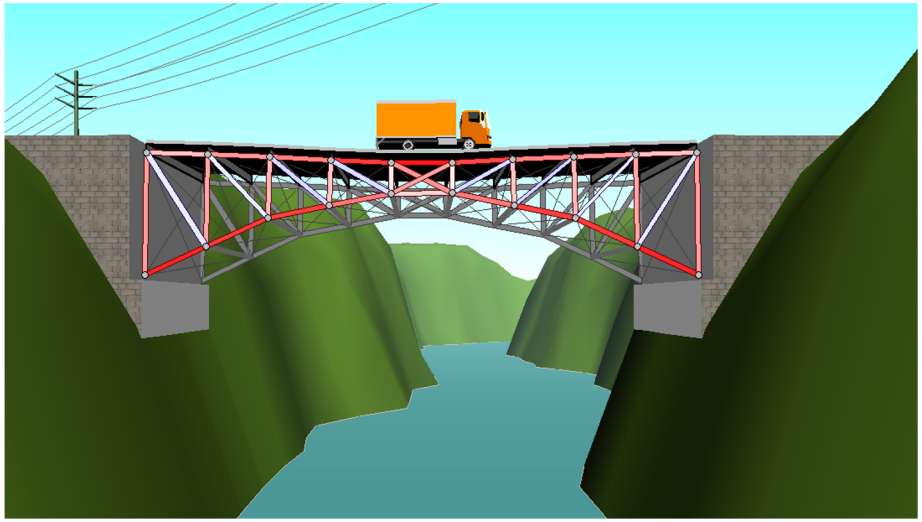
- Design a bridge while simultaneously minimizing the cost of it
- The bridge can cross at any elevation up to 24 meters above high water level and if it is lower than 24 meters excavation of the site is required
- Must not exceed an elevation of 32.5 meters above high water level
- The bridge may contain standard abutments, arch abutments, or one pier
- If using anchorages they must be located 8 meters behind the abutments
- The truss may have a maximum of 50 joints and a maximum of 120 members
- The deck of the bridge can use medium-strength or high-strength concrete but must be 10 meters wide for two lanes of traffic
- The members can be made of carbon steel, high-strength, low-alloy steel or quenched and tempered steel
- The members can be solid bars or hollow tubes
- The bridge must be able to withstand the weight of the reinforced deck, the asphalt, the main truss, and the truck loads

Research Summary

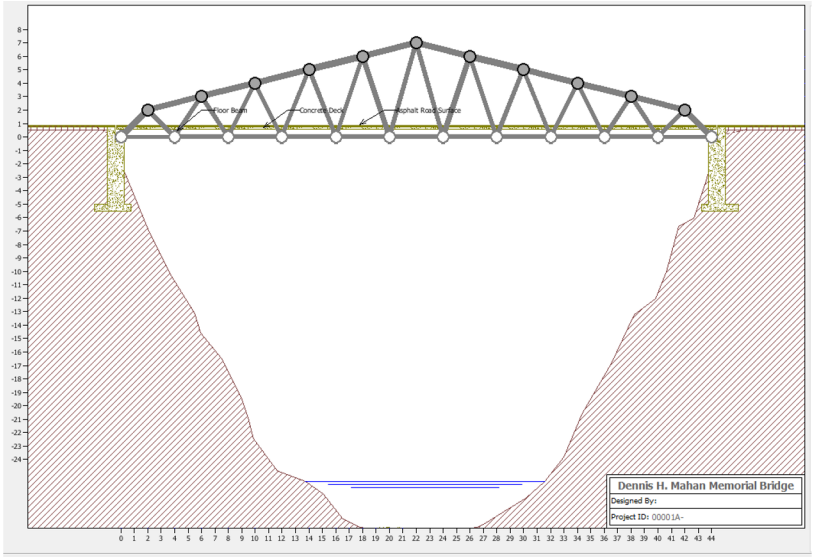
- The lower the bridge, the higher the cost due to price of excavation
- Piers provide stability, yet increase the total cost
- The closer the arch abutments, the less they cost
- The more cable anchorages, the more expensive
- High strength deck material is more expensive than medium-strength
- Least expensive to Most: Carbon Steel, High-Strength, Quenched
- Hollow Tubes are cheaper than solid bars
- The larger the cross section, the more expensive

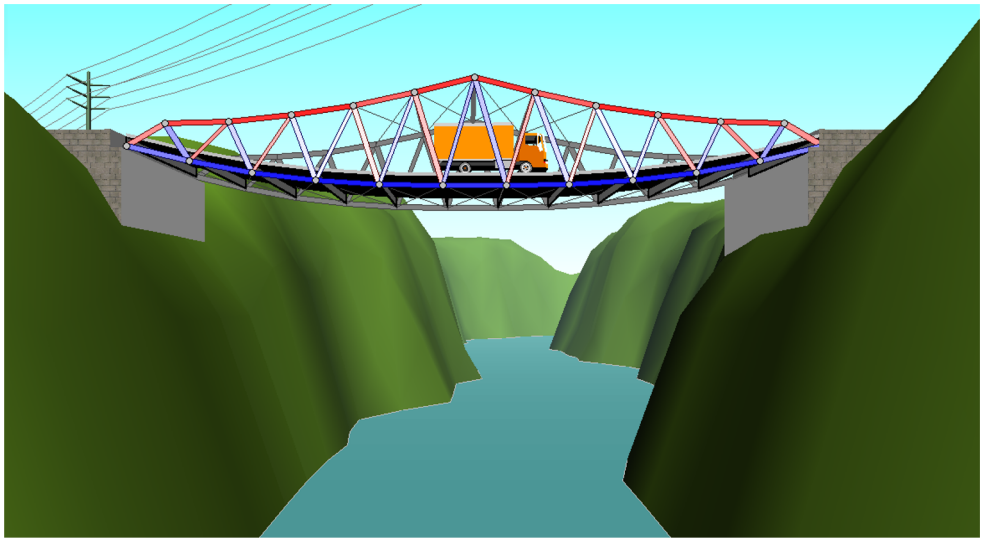
[redacted]'s First Bridge



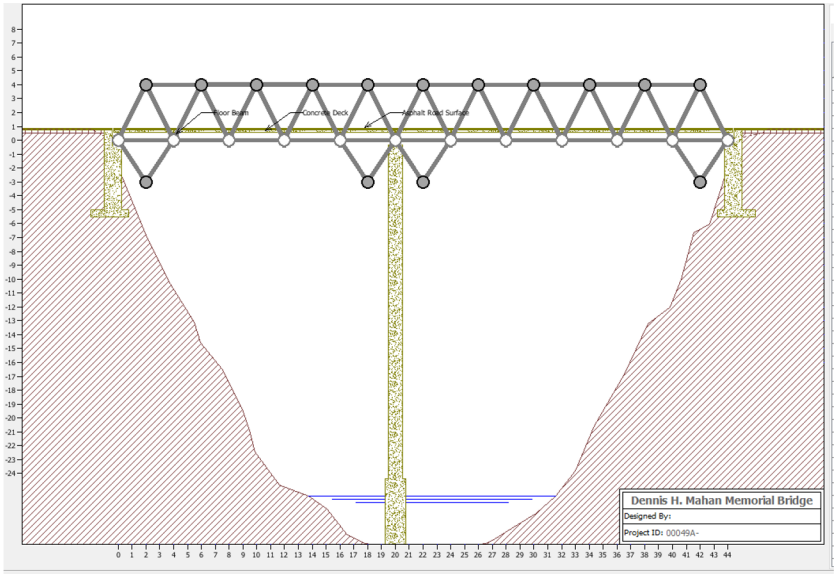


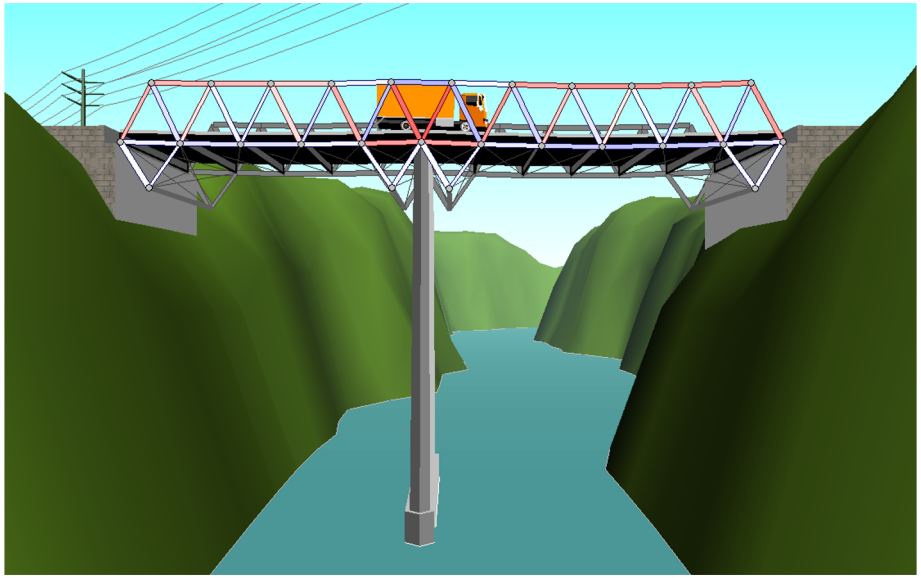
[redacted]'s Second Bridge



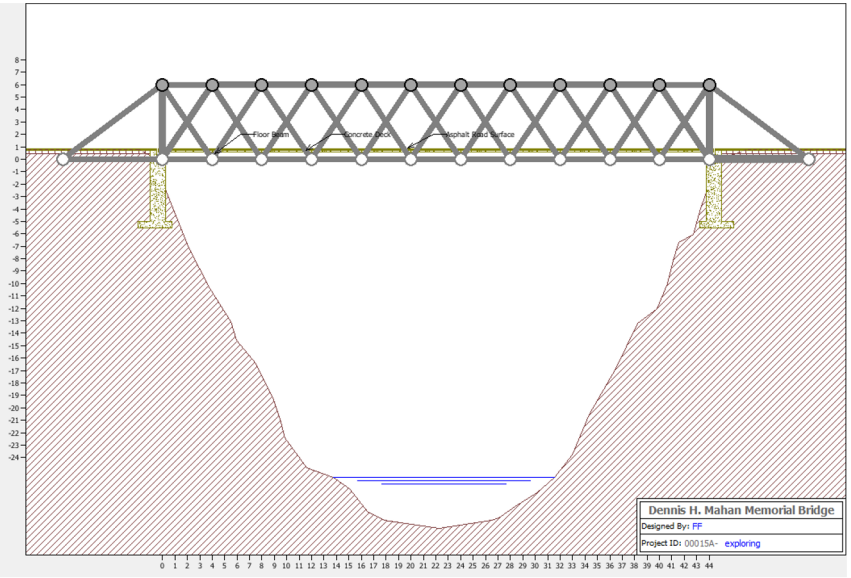


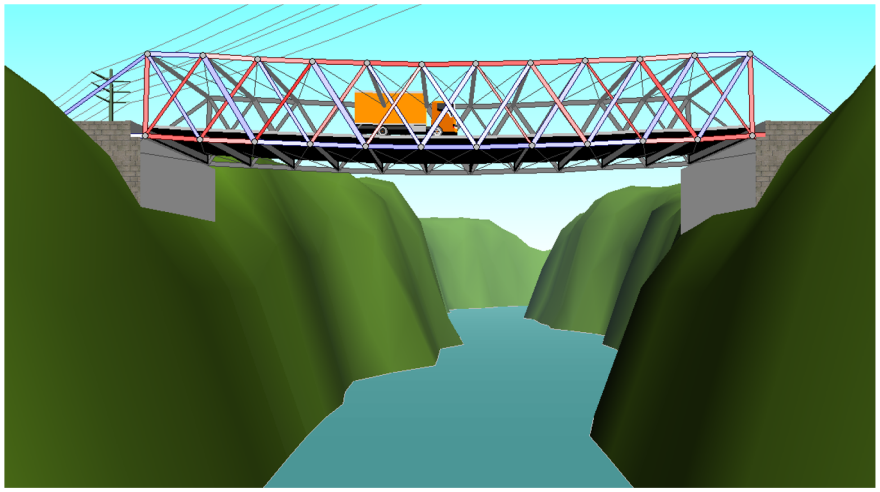
[redacted]'s Third Bridge



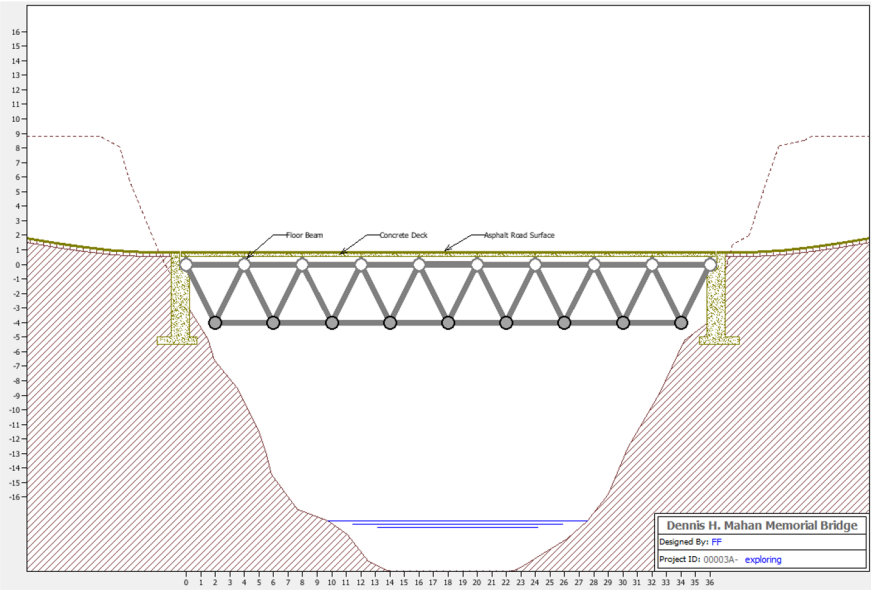


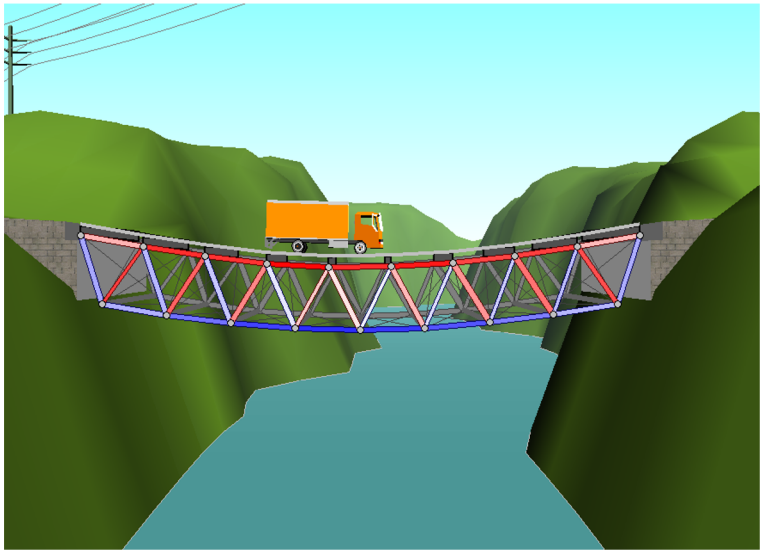
[redacted]'s First Bridge





[redacted]'s Second Bridge





Final Design Justification

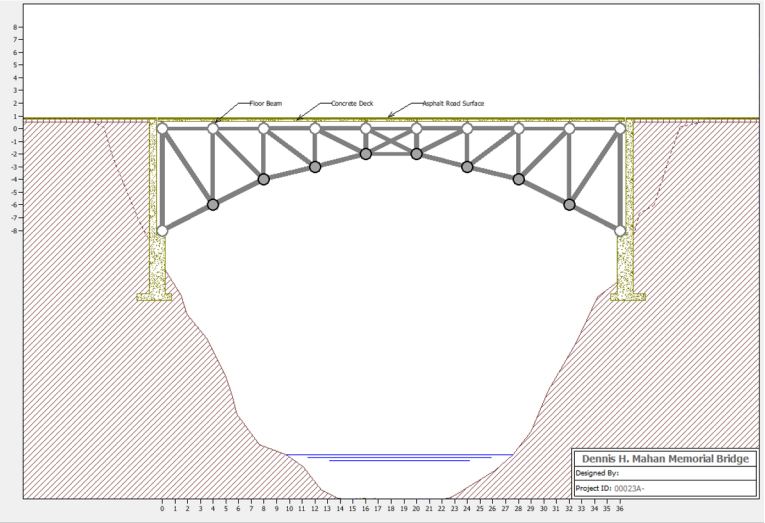
0-5
5 denotes the most sufficient for the given category

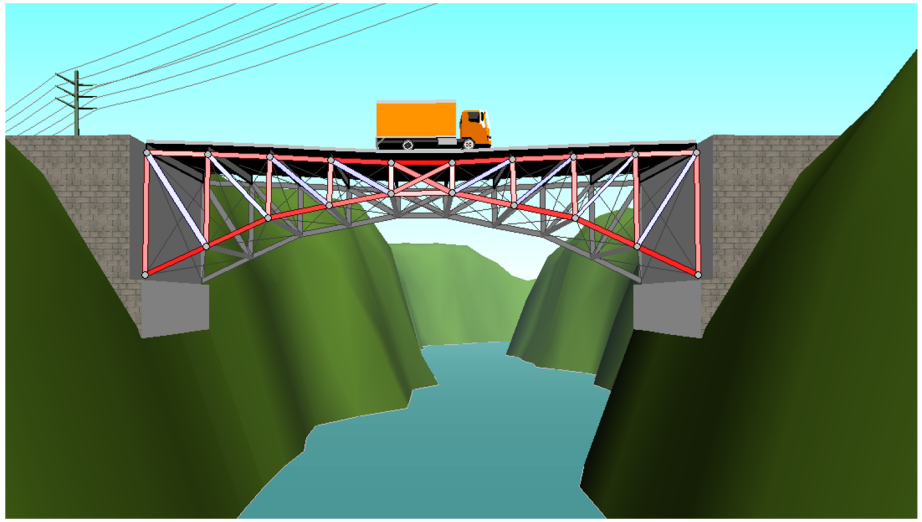
Criteria

Ideas

	Site Cost	Safety	Feasibility	Number of Members	Total Cost	Totals
[redacted]'s 1st	3	3	5	4	4	19
[redacted]'s 2nd	5	1	5	3	3	17
[redacted]'s 3rd	4	4	5	2	1	16
[redacted]'s 1st	2	3	2	5	5	17
[redacted]s 2nd	1	4	1	1	2	9

Final Bridge Design





Final Bridge Reports

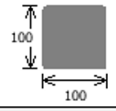
Material Properties:

Material	Carbon Steel
Yield Stress (Fy)	250000 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	Solid Bar
Cross-Section Size	100x100
Area	0.0100 sq. meters
Moment of Inertia	8.33E-06 meters^4
Member Length	4.00 meters

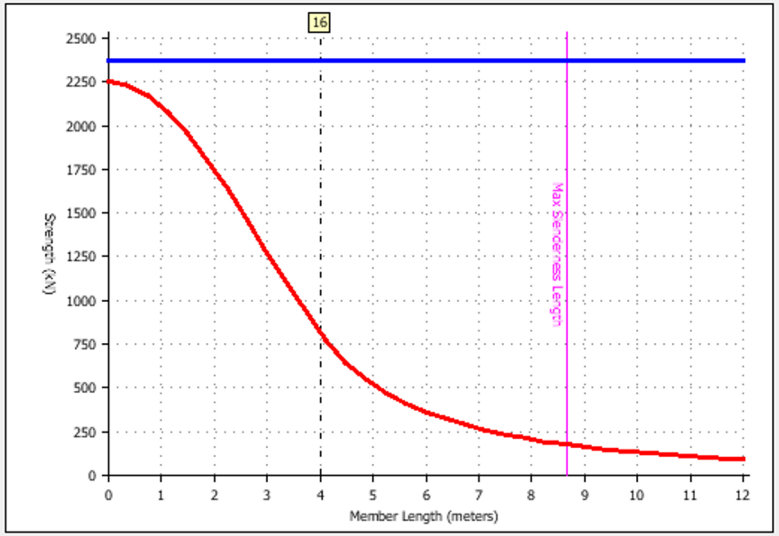
Section (mm):



Cost:

Unit Cost	$337.55 per meter
Member Cost	$1350.20

Strength vs. Length: Graph all tabs Member:



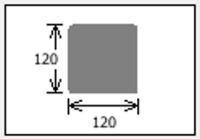
Material Properties:

Material	Carbon Steel
Yield Stress (Fy)	250000 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	Solid Bar
Cross-Section Size	120x120
Area	0.0144 sq. meters
Moment of Inertia	1.73E-05 meters^4
Member Length	4.00 meters

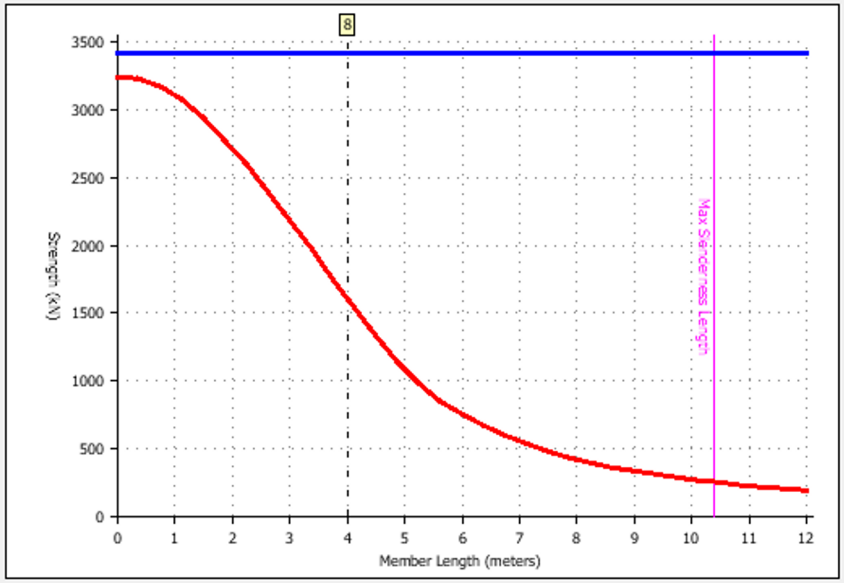
Section (mm):



Cost:

Unit Cost	$486.07 per meter
Member Cost	$1944.29

Strength vs. Length: Graph all tabs Member:



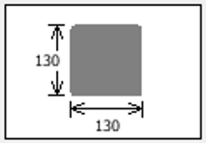
Material Properties:

Material	Carbon Steel
Yield Stress (Fy)	250000 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	Solid Bar
Cross-Section Size	130x130
Area	0.0169 sq. meters
Moment of Inertia	2.38E-05 meters^4
Member Length	--

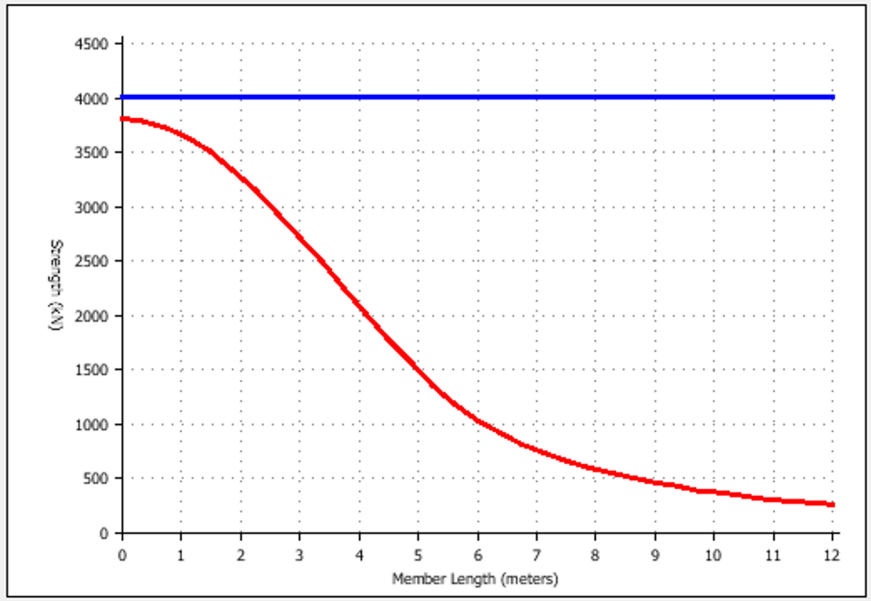
Section (mm):



Cost:

Unit Cost	$570.46 per meter
Member Cost	--

Strength vs. Length: Graph all tabs Member:



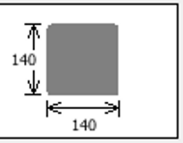
Material Properties:

Material	Carbon Steel
Yield Stress (Fy)	250000 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	Solid Bar
Cross-Section Size	140x140
Area	0.0196 sq. meters
Moment of Inertia	3.20E-05 meters^4
Member Length	4.47 meters

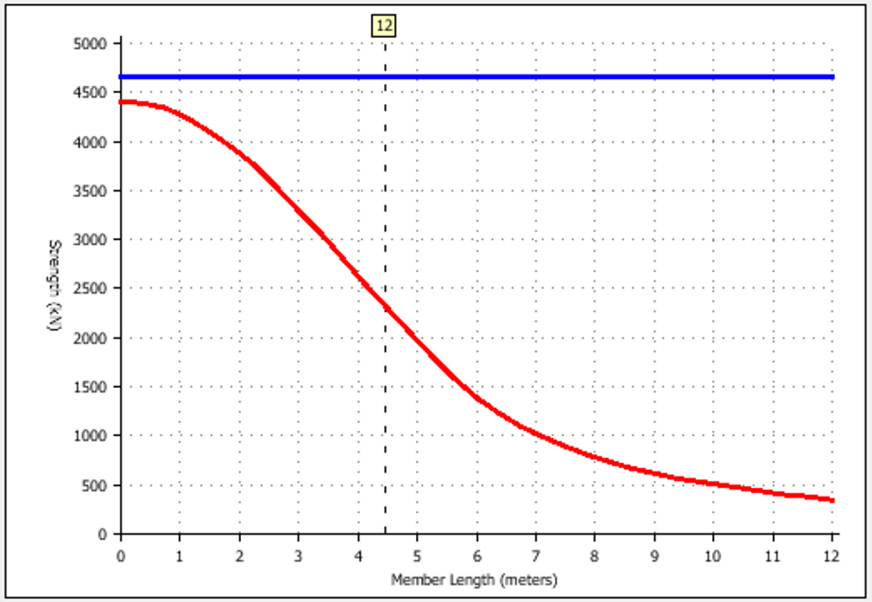
Section (mm):



Cost:

Unit Cost	$661.60 per meter
Member Cost	$2958.76

Strength vs. Length: Graph all tabs Member:



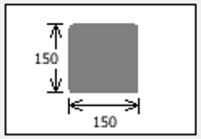
Material Properties:

Material	Carbon Steel
Yield Stress (Fy)	250000 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	Solid Bar
Cross-Section Size	150x150
Area	0.0225 sq. meters
Moment of Inertia	4.22E-05 meters^4
Member Length	8.00 meters

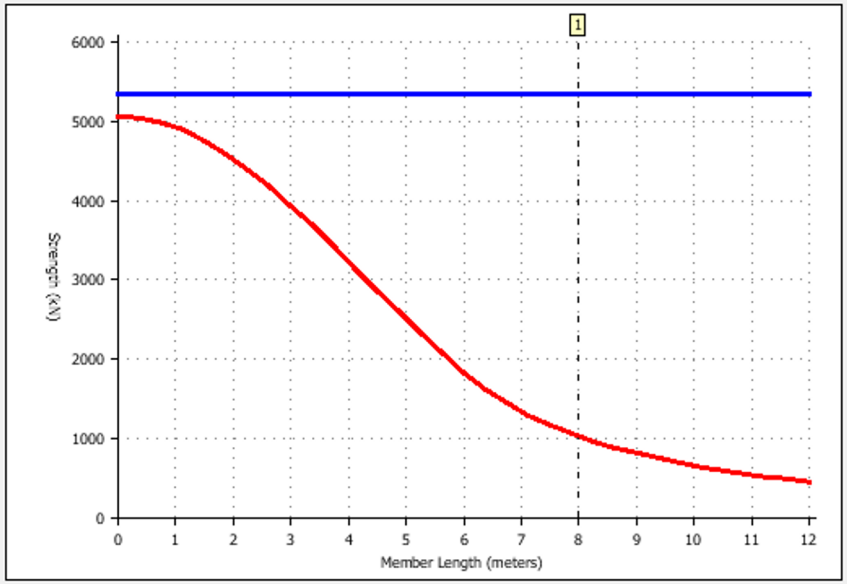
Section (mm):



Cost:

Unit Cost	$759.49 per meter
Member Cost	$6075.90

Strength vs. Length: Graph all tabs Member:



Final Bridge Report Continued

Load Test Results

#	Material Type	Cross Section	Size (mm)	Length (m)	Slender-ness	Compression Force/Strength	Tension Force/Strength
1	CS	Bar	150	8.00	184.75	0.86	0.00
2	CS	Bar	150	8.00	184.75	0.78	0.00
3	CS	Bar	100	4.00	138.56	0.52	0.00
4	CS	Bar	100	4.00	138.56	0.96	0.00
5	CS	Bar	120	4.00	115.47	0.74	0.00
6	CS	Bar	120	4.00	115.47	0.84	0.00
7	CS	Bar	100	4.00	138.56	0.91	0.00
8	CS	Bar	120	4.00	115.47	0.86	0.00
9	CS	Bar	120	4.00	115.47	0.76	0.00
10	CS	Bar	100	4.00	138.56	0.96	0.00
11	CS	Bar	100	4.00	138.56	0.48	0.00
12	CS	Bar	140	4.47	110.66	0.86	0.00
13	CS	Bar	140	4.47	110.66	0.77	0.00
14	CS	Bar	130	4.12	109.87	0.78	0.00
15	CS	Bar	130	4.12	109.87	0.58	0.00
16	CS	Bar	100	4.00	138.56	0.37	0.00
17	CS	Bar	130	4.12	109.87	0.57	0.00
18	CS	Bar	130	4.12	109.87	0.77	0.00
19	CS	Bar	140	4.47	110.66	0.78	0.00
20	CS	Bar	140	4.47	110.66	0.86	0.00
21	CS	Bar	130	6.00	159.88	0.80	0.00
22	CS	Bar	130	4.00	106.59	0.41	0.00
23	CS	Bar	120	3.00	86.60	0.29	0.00
24	CS	Bar	140	2.00	49.49	0.08	0.01
25	CS	Bar	140	2.00	49.49	0.07	0.02
26	CS	Bar	120	3.00	86.60	0.26	0.00
27	CS	Bar	130	4.00	106.59	0.37	0.00
28	CS	Bar	130	6.00	159.88	0.74	0.00
29	CS	Bar	140	7.21	178.43	0.00	0.16
30	CS	Bar	130	5.66	150.74	0.00	0.16
31	CS	Bar	130	5.00	133.23	0.00	0.20
32	CS	Bar	130	4.47	119.17	0.04	0.15
33	CS	Bar	120	4.47	129.10	0.51	0.00
34	CS	Bar	120	4.47	129.10	0.56	0.00
35	CS	Bar	130	4.47	119.17	0.06	0.12
36	CS	Bar	130	5.00	133.23	0.00	0.18
37	CS	Bar	130	5.66	150.74	0.00	0.14
38	CS	Bar	140	7.21	178.43	0.00	0.15

Cost Report

Cost Calculations Report

Type of Cost	Item	Cost Calculation	Cost
Material Cost (M)	Carbon Steel Solid Bar	(22650.2 kg) x ($4.30 per kg) x (2 Trusses) =	$194,791.33
Connection Cost (C)		(20 Joints) x (400.0 per joint) x (2 Trusses) =	$16,000.00
Product Cost (P)	6 - 100x100 mm Carbon Steel Bar	($1,000.00 per Product) =	$1,000.00
	8 - 120x120 mm Carbon Steel Bar	($1,000.00 per Product) =	$1,000.00
	14 - 130x130 mm Carbon Steel Bar	($1,000.00 per Product) =	$1,000.00
	8 - 140x140 mm Carbon Steel Bar	($1,000.00 per Product) =	$1,000.00
	2 - 150x150 mm Carbon Steel Bar	($1,000.00 per Product) =	$1,000.00
Site Cost (S)	Deck Cost	(9 4-meter panels) x ($4,700.00 per panel) =	$42,300.00
	Excavation Cost	(0 cubic meters) x ($1.00 per cubic meter) =	$0.00
	Abutment Cost	(2 arch abutments) x ($20,500.00 per abutment) =	$41,000.00
	Pier Cost	No pier =	$0.00
	Cable Anchorage Cost	No anchorages =	$0.00
Total Cost	**M + C + P + S**	**$194,791.33 + $16,000.00 + $5,000.00 + $83,300.00 =**	**$299,091.33**

How does the type and direction of stress applied affect the selection of the material type and the cross-sectional area?

Out of the three materials (carbon steel, high-strength low-alloy steel or quenched and tempered steel), carbon steel can yield the least amount of stress while quenched steel can yield the most stress. Furthermore, the larger the cross section of the bar the more stress it will be able to yield. This means that in areas of the bridge that face high amounts of pressure and stress, the member material would need to be changed to either high-strength steel or quenched steel. Likewise, if the designer does not want to change the material, then the cross-sectional area would need to be increased to support the stress.

How can the forces of compression and tension work together to make a stronger bridge?

Tension and compression are forces that work together and in some way “cancel” each other out. Compression force “compresses” or applies pressure to an area of a bridge whereas tension force tends to stretch an area. These forces counteract one another while reaching equilibrium, thus building a stronger bridge.

Sources

West Point Bridge Designer 2016:

Ressler, S. (n.d.). Retrieved from http://bridgedesigner.org/about/