9/10 STEM ELECTIVE - CIVIL ENGINEERING

TASK 1 - MOST ECONOMICAL FUNCTIONING BRIDGE

COMPLETED ON 12/6/2017

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ABSTRACT

SCOPE

Task 1 requires students to design a theoretical Cable-Stayed, Suspension, Beam, Truss, or Arch bridge, with the use of CAD (computer aided design) technology.

OBJECTIVES

- This bridge must uphold its own weight, inclusive of its reinforced concrete deck, as well as the weight of the standard truck loading.
- The price of the bridge must remain as low as possible, whilst being able to pass a load test.

OTHER

Creative independence exists for all other design considerations, inclusive of the deck elevation, is allowed. However, the design must be unique, and cannot replicate any sample bridge files. Mentoring, and collaboration is key to the achievement of this task, as well as research on materials that would best suit a cost-effective motive. The software required to complete this task is Westpoint Bridge Designer 2014 for the design of the bridge, and Microsoft Word for the report. West Point, provided free of charge, allows the student access to:

- A drawing board, that considers the accurate span length, height and supports
- An automatic calculation of the loads and resulting member forces
- A load test that performs structural safety checks and determines whether the bridge is stable
- An automatic calculation of the cost with every alteration

Lastly, a detailed report on Microsoft Word of the end design and process must be completed and submitted.

INTRODUCTION

Within the 9/10 Elective STEM, engineering is the primary focus. This term, students studied the fundamentals of civil engineering. The purpose of this task was to test their knowledge of this and apply them to a real-world situation, through CAD (computer aided design) technology. Individually, the students would act as mock civil engineers, designing the most structurally sound and inexpensive two-lane bridge, above a river valley. The cost of the bridge must remain as low as possible, whilst still passing the load test. Mentoring, and collaboration was key to the achievement of this task. The software used to complete this task is West Point Bridge Designer 2014, and Microsoft Word.

Within this report, the analysis will reveal how the Arch bridge came to be the most successful, the results summary to detail the progressive cost of the bridge, conclusion and recommendations to summarise the report.

ANALYSIS

GENERAL DESIGN CONSIDERATIONS

This report details the process of the most successful design; an Arch bridge (Andria – 167,420.83). Below are the applied general design considerations:

$123,500.00 (Includes cost of deck, excavation, and supports; not steel trusses.) Site Condition: 06C

Deck Cost	(6 4-meter panels) x ($5,000.00 per panel) =	$30,000.00
Excavation Cost	(85,000 cubic meters) x ($1.00 per cubic meter) =	$85,000.00
Abutment Cost	(2 standard abutments) x ($4,250.00 per abutment) =	$8,500.00
Pier Cost	No pier =	$0.00
Anchorage Cost	No anchorages =	$0.00

The deck was constructed from high-strength concrete (0.15m thick), and was set to bear a load of a standard 225 kN truck, whilst having two lanes.

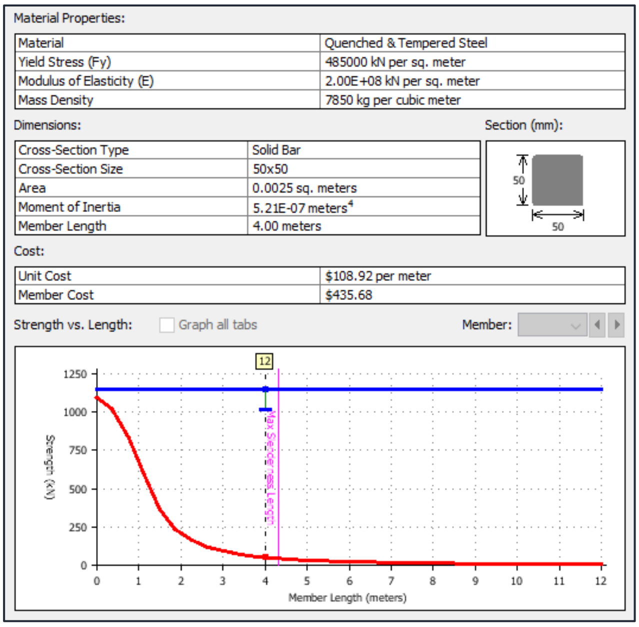
The decision for these general design considerations came after tedious testing that proved a higher-strength concrete, overall was the most economical option. Whilst being the more expensive option, being of higher strength means having lighter deck members, and an overall cheaper cost. It also proved that an excavation to 4 metres was the most economical. Any higher would add too many members, and/or any lower would increase the size of the members; these options increased the price, yet at an excavation of 4 metres, was the perfect medium. The choice of having a standard abutment and no pier contributed to the motive of creating an arch bridge. The purpose of not having any anchorages contributes to this low budget motive as well.

EXPERIMENTATION OF MATERIALS

A profile of which materials to use, was aided by the article, 'Metallurgy Matters: Carbon content, steel classifications, and alloy steels'. Through this article, I could identify which materials were appropriate for where, and which were most economical, as well as through trial and error on West Point Bridge Designer.

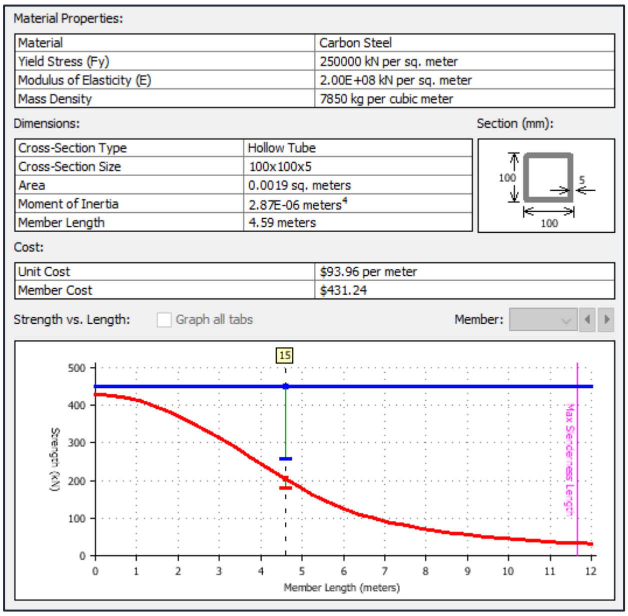
The triple bottom line – social, environmental, and economical components of the bridge was the focus for the use of materials. The social component focuses on having the bridge safe and adequate for applications. This is demonstrated through the construction of the deck, having been made from quenched and tempered steel to ensure strength, at the sacrifice of a costly price. Using this strong material allows for the bar the slim down as much as possible. The deck members were solid bars to ensure a stable deck. This contributed to the low-budget motive, whilst remaining adequate and safe.

MEMBERS 8 THROUGH TO 13

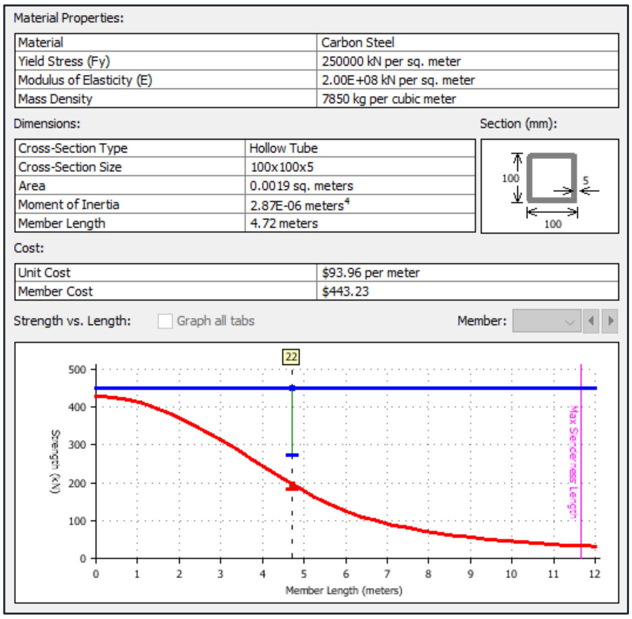


The environmental component focuses on not overusing materials wherever isn't necessary. This is demonstrated through the construction of members 14, 15, 22, and 23, where carbon steel was used to ensure the ability to be compressed and under tension, whilst remaining slimming and cost-effective. These bars were hollowed to ensure elasticity.

MEMBER 15



MEMBER 22



MEMBERS 14 AND 23

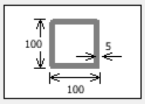
Material Properties:

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	Hollow Tube
Cross-Section Size	100x100x5
Area	0.0019 sq. meters
Moment of Inertia	2.87E-06 meters^4
Member Length	2.80 meters

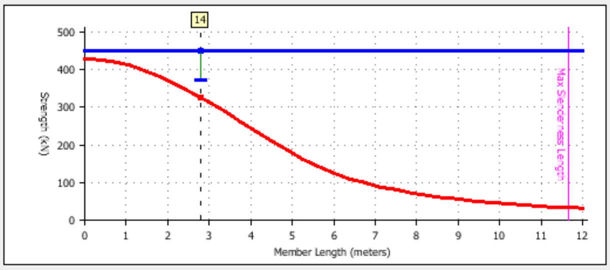
Section (mm):



Cost:

Unit Cost	$93.96 per meter
Member Cost	$262.64

Strength vs. Length: Graph all tabs Member:



The economical component focuses on making the bridge as cheap as possible whilst not sacrificing performance. This is demonstrated with high-strength low alloy steel in members 1 through 7, and 16 through 21. These areas required the strongest material at a low-budget price. These bars were hollowed to ensure elasticity. If carbon steel was used as the majority, the size of the members would increase and would stress the deck, and if quenched and tempered steel was the majority, the starting price alone would not be the most economical option.

MEMBERS 17 AND 19

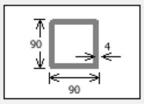
Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 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	5.30 meters

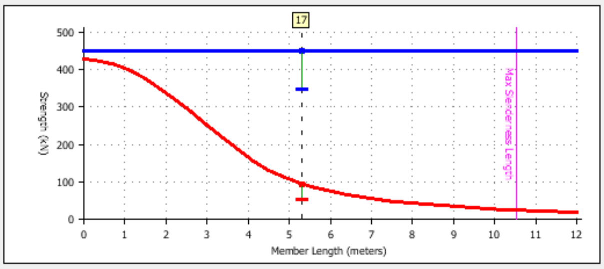
Section (mm):



Cost:

Unit Cost	$75.61 per meter
Member Cost	$400.54

Strength vs. Length: Graph all tabs Member:



MEMBERS 18 AND 20

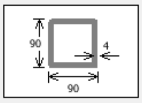
Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 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	5.48 meters

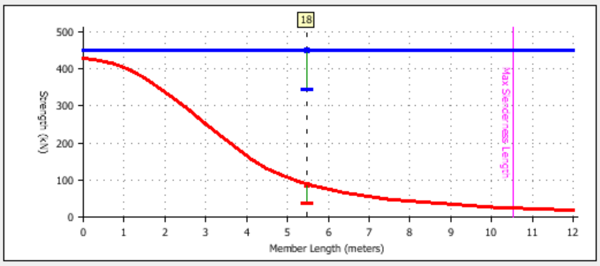
Section (mm):



Cost:

Unit Cost	$75.61 per meter
Member Cost	$414.57

Strength vs. Length: Graph all tabs Member:



MEMBER 16

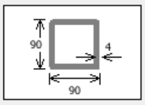
Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 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	4.37 meters

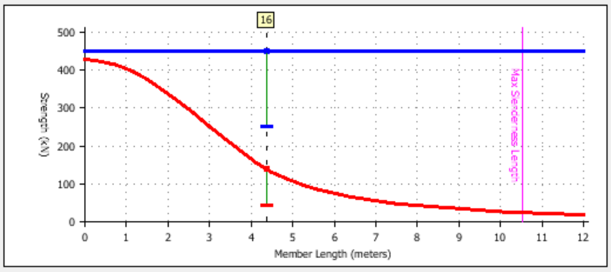
Section (mm):



Cost:

Unit Cost	$75.61 per meter
Member Cost	$330.12

Strength vs. Length: Graph all tabs Member:



MEMBER 21

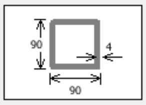
Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 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	4.27 meters

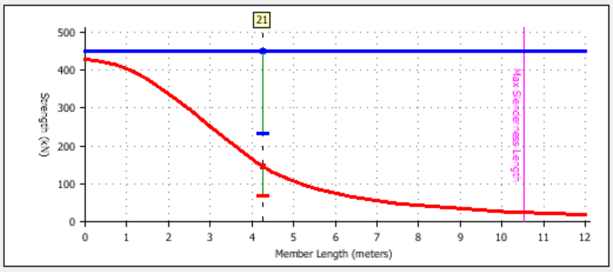
Section (mm):



Cost:

Unit Cost	$75.61 per meter
Member Cost	$323.01

Strength vs. Length: Graph all tabs Member:



MEMBERS 1 AND 7

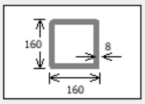
Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 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	3.72 meters

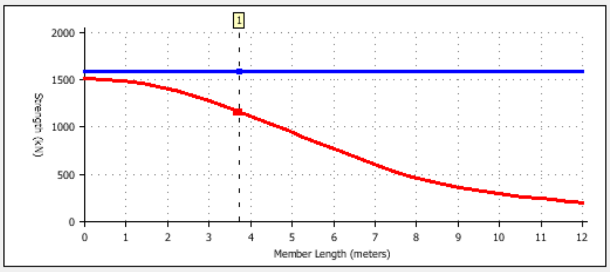
Section (mm):



Cost:

Unit Cost	$267.28 per meter
Member Cost	$993.34

Strength vs. Length: Graph all tabs Member:



MEMBER 2

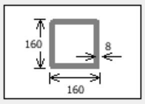
Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 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	3.81 meters

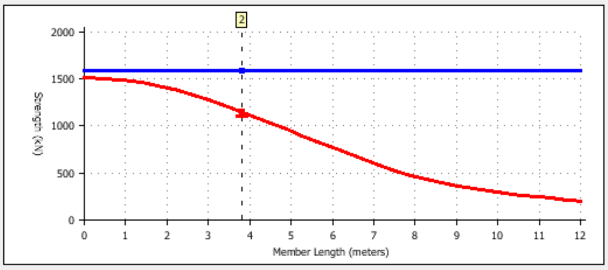
Section (mm):



Cost:

Unit Cost	$267.28 per meter
Member Cost	$1017.76

Strength vs. Length: Graph all tabs Member:



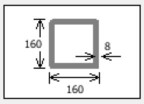
MEMBER 3

Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 kN per sq. meter
Modulus of Elasticity (E)	2.00E+08 kN per sq. meter
Mass Density	7850 kg per cubic meter

Dimensions: Section (mm):

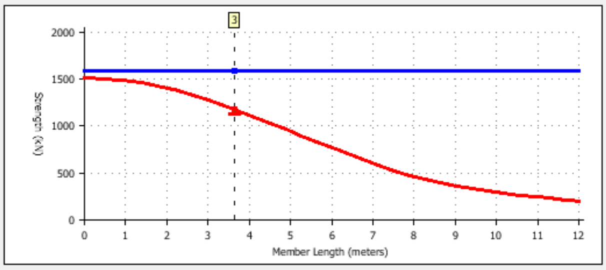
Cross-Section Type	Hollow Tube
Cross-Section Size	160x160x8
Area	0.0049 sq. meters
Moment of Inertia	1.88E-05 meters^4
Member Length	3.64 meters



Cost:

Unit Cost	$267.28 per meter
Member Cost	$972.90

Strength vs. Length: Graph all tabs Member:



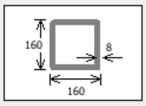
MEMBER 4

Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 kN per sq. meter
Modulus of Elasticity (E)	2.00E+08 kN per sq. meter
Mass Density	7850 kg per cubic meter

Dimensions: Section (mm):

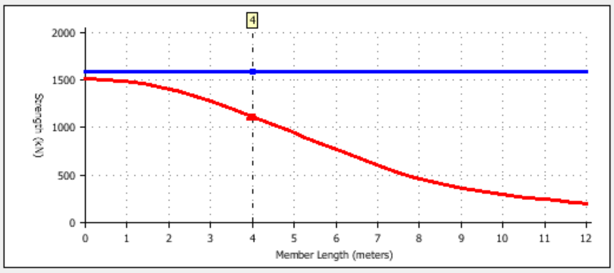
Cross-Section Type	Hollow Tube
Cross-Section Size	160x160x8
Area	0.0049 sq. meters
Moment of Inertia	1.88E-05 meters^4
Member Length	4.00 meters



Cost:

Unit Cost	$267.28 per meter
Member Cost	$1069.11

Strength vs. Length: Graph all tabs Member:



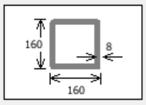
MEMBER 5

Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 kN per sq. meter
Modulus of Elasticity (E)	2.00E+08 kN per sq. meter
Mass Density	7850 kg per cubic meter

Dimensions: Section (mm):

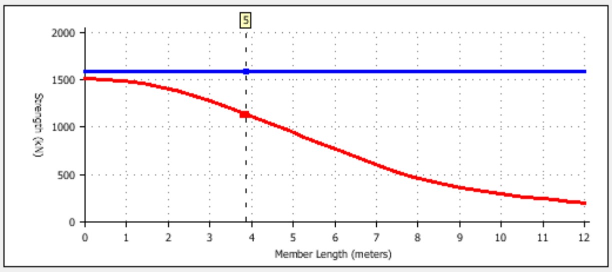
Cross-Section Type	Hollow Tube
Cross-Section Size	160x160x8
Area	0.0049 sq. meters
Moment of Inertia	1.88E-05 meters^4
Member Length	3.88 meters



Cost:

Unit Cost	$267.28 per meter
Member Cost	$1037.31

Strength vs. Length: Graph all tabs Member:



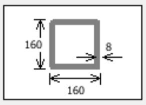
MEMBER 6

Material Properties:

Material	High-Strength Low-Alloy Steel
Yield Stress (Fy)	345000 kN per sq. meter
Modulus of Elasticity (E)	2.00E+08 kN per sq. meter
Mass Density	7850 kg per cubic meter

Dimensions: Section (mm):

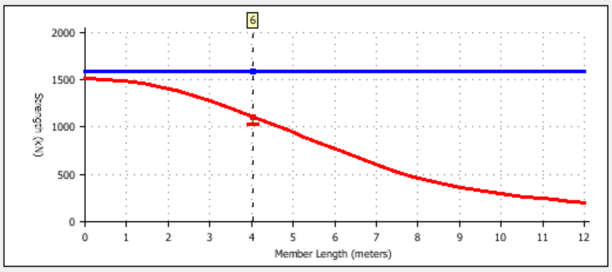
Cross-Section Type	Hollow Tube
Cross-Section Size	160x160x8
Area	0.0049 sq. meters
Moment of Inertia	1.88E-05 meters^4
Member Length	4.04 meters



Cost:

Unit Cost	$267.28 per meter
Member Cost	$1079.50

Strength vs. Length: Graph all tabs Member:



Therefore, the decision for each component contributes to a cost-effective motive.

OTHER

The trend I recognised when designing this bridge was that it was more cost-effective to buy in bulk. Therefore, all groups of members are similar in material, size, and position. Together, in the form of an arch bridge the members produced the most cost-effective solution.

LOAD TEST RESULTS

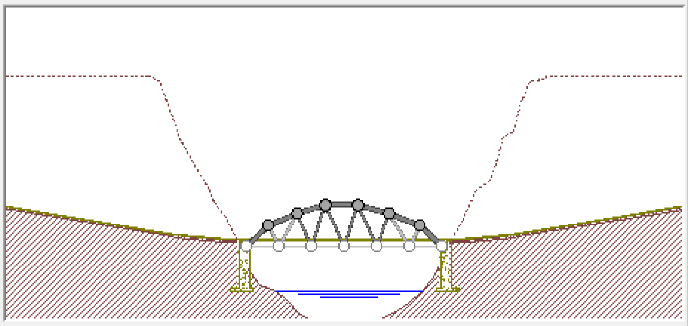
Load Another Iteration

Select an Iteration:

List View | Tree View

Status	Iteration	Cost	Project ID
	105	$167,420.83	00006C-
	106	$167,413.40	00006C-
	107	$167,410.67	00006C-
	108	$167,417.00	00006C-
	109	$167,425.94	00006C-
	110	$167,420.83	00006C-

Preview:



Load Test Results

#	Material Type	Cross Section	Size (mm)	Length (m)	Slender-ness	Compression Force	Compression Strength	Compression Status	Tension Force	Tension Strength	Tension Status
1	HSS	Tube	160	3.72	59.81	1146.80	1164.75	OK	0.00	1594.18	OK
2	HSS	Tube	160	3.81	61.28	1104.97	1149.79	OK	0.00	1594.18	OK
3	HSS	Tube	160	3.64	58.58	1133.91	1177.14	OK	0.00	1594.18	OK
4	HSS	Tube	160	4.00	64.37	1093.63	1117.80	OK	0.00	1594.18	OK
5	HSS	Tube	160	3.88	62.46	1121.85	1137.69	OK	0.00	1594.18	OK
6	HSS	Tube	160	4.04	65.00	1030.49	1111.25	OK	0.00	1594.18	OK
7	HSS	Tube	160	3.72	59.81	1067.73	1164.75	OK	0.00	1594.18	OK
8	QTS	Bar	50	4.00	277.13	0.00	50.89	OK	848.56	1151.88	OK
9	QTS	Bar	50	4.00	277.13	0.00	50.89	OK	989.58	1151.88	OK
10	QTS	Bar	50	4.00	277.13	0.00	50.89	OK	975.11	1151.88	OK
11	QTS	Bar	50	4.00	277.13	0.00	50.89	OK	1007.74	1151.88	OK
12	QTS	Bar	50	4.00	277.13	0.00	50.89	OK	1014.93	1151.88	OK
13	QTS	Bar	50	4.00	277.13	0.00	50.89	OK	790.06	1151.88	OK
14	CS	Tube	100	2.80	71.97	0.00	325.50	OK	373.57	451.25	OK
15	CS	Tube	100	4.59	118.17	181.45	205.02	OK	258.31	451.25	OK
16	HSS	Tube	90	4.37	124.22	44.94	139.40	OK	251.23	450.98	OK
17	HSS	Tube	90	5.30	150.72	52.19	94.70	OK	348.64	450.98	OK
18	HSS	Tube	90	5.48	156.00	38.59	88.40	OK	344.26	450.98	OK
19	HSS	Tube	90	5.30	150.72	93.89	94.70	OK	276.00	450.98	OK
20	HSS	Tube	90	5.48	156.00	37.08	88.40	OK	411.35	450.98	OK
21	HSS	Tube	90	4.27	121.55	69.68	145.61	OK	231.48	450.98	OK
22	CS	Tube	100	4.72	121.46	182.45	196.69	OK	274.64	451.25	OK
23	CS	Tube	100	2.80	71.97	0.00	325.50	OK	372.81	451.25	OK

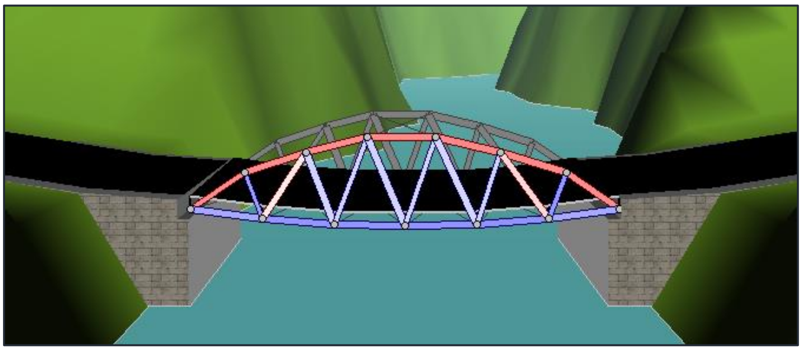
The above tables shows the experimentation of the arch bridge, passing its load test.

RESULTS SUMMARY

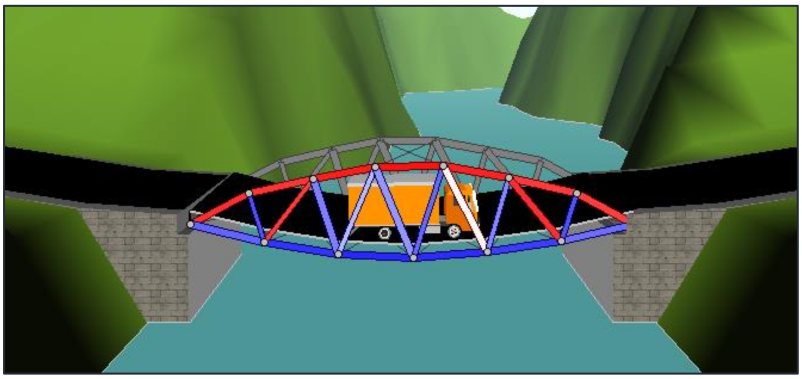
The result of the bridge was an arch bridge with the price of $167,420.83. The negative limitations during the designing of this bridge were as follows:

- Inexperience in the program – this was improved through continued use of the program.
- Trial and error strategy which provided more error and then success – this was improved through continued use of the program.

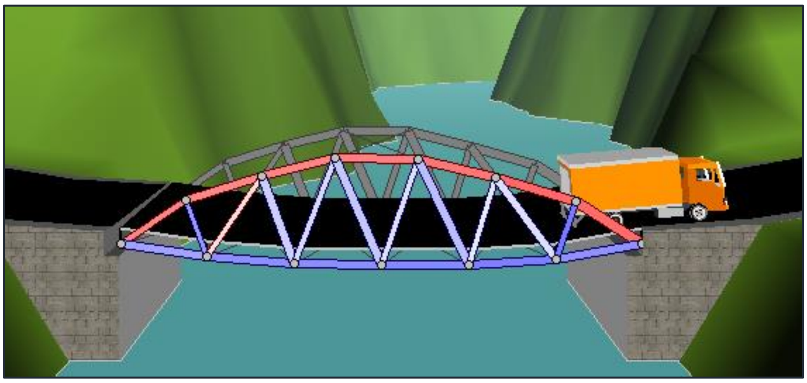
BEFORE LOAD TEST



DURING LOAD TEST



AFTER LOAD TEST



Above shows this bridge passing its load test.

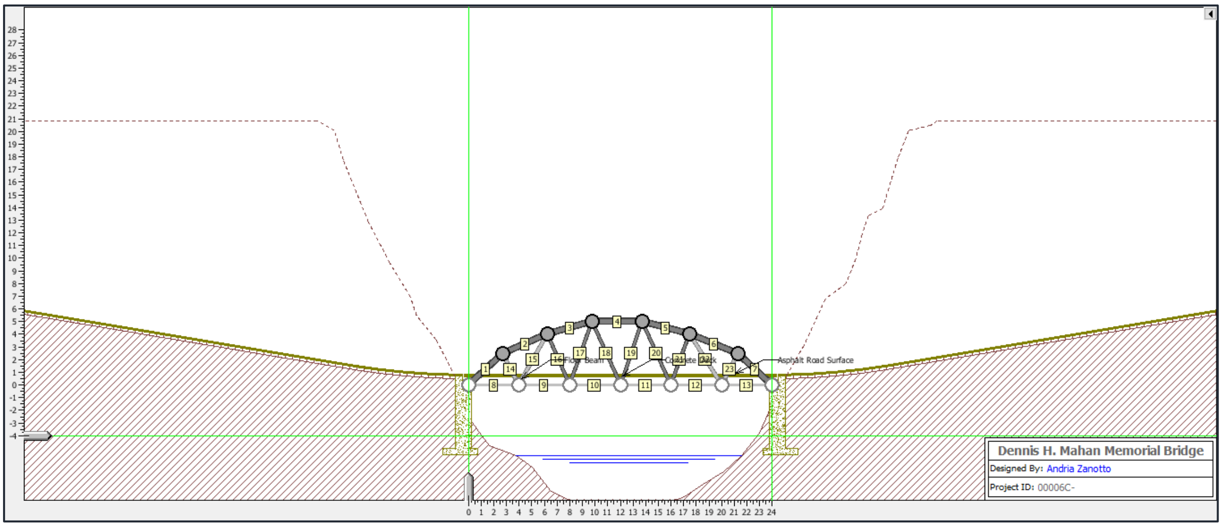
COST CALCULATION REPORT

Cost Calculations Report

Type of Cost	Item	Cost Calculation	Cost
Material Cost (M)	Carbon Steel Hollow Tube	(222.2 kg) x ($6.30 per kg) x (2 Trusses) =	$2,799.49
	High-Strength Low-Alloy Steel Hollow Tube	(1349.5 kg) x ($7.00 per kg) x (2 Trusses) =	$18,893.24
	Quenched & Tempered Steel Solid Bar	(471.0 kg) x ($5.55 per kg) x (2 Trusses) =	$5,228.10
Connection Cost (C)		(13 Joints) x (500.0 per joint) x (2 Trusses) =	$13,000.00
Product Cost (P)	6 - 50x50 mm Quenched & Tempered Steel Bar	($1,000.00 per Product) =	$1,000.00
	6 - 90x90x4 mm High-Strength Low-Alloy Steel Tube	($1,000.00 per Product) =	$1,000.00
	4 - 100x100x5 mm Carbon Steel Tube	($1,000.00 per Product) =	$1,000.00
	7 - 160x160x8 mm High-Strength Low-Alloy Steel Tube	($1,000.00 per Product) =	$1,000.00
Site Cost (S)	Deck Cost	(6 4-meter panels) x ($5,000.00 per panel) =	$30,000.00
	Excavation Cost	(85,000 cubic meters) x ($1.00 per cubic meter) =	$85,000.00
	Abutment Cost	(2 standard abutments) x ($4,250.00 per abutment) =	$8,500.00
	Pier Cost	No pier =	$0.00
	Cable Anchorage Cost	No anchorages =	$0.00
Total Cost	**M + C + P + S**	**$26,920.83 + $13,000.00 + $4,000.00 + $123,500.00 =**	**$167,420.83**

This table details the cost of all the elements of the bridge.

DRAWING BOARD



Above represents the final design of the arch bridge.

CONCLUSION/RECOMMENDATIONS

In conclusion, the most economical, and functioning bridge, was the arch design. It supported its own weight as well as the weight of the truck load. The cost of the bridge remained as low as possible, at $167,420.83, and it passed the load test. The aid of CAD made this possible, with West Point Bridge Designer 2014.

ACKNOWLEDGEMENTS

Collaboration was key to achieving this task to gain an idea of what is successful. Those who contributed to this task are as follows:

- Mentor – Mr Preston
- Fellow cohorts – Anthony Carusi, Jaykumar Shah

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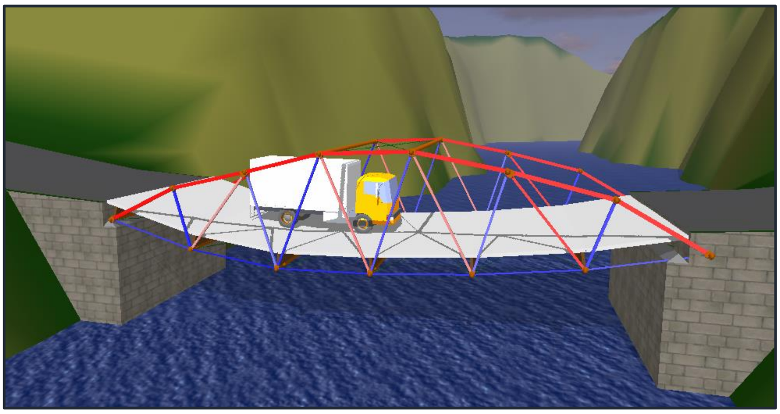
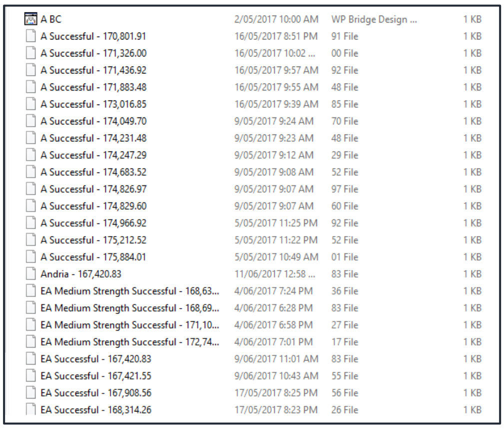
www.thefabricator.com/article/metalsmaterials/carbon-content-steel-classifications-and-alloy-steels	Bob Capudean	Metal material qualities
www.griffith-h.schools.nsw.edu.au/ghs-moodle	Mr Preston	Assessment Task Information
www.fluor.com/mobile/about_fluor/newsroom/pages/engineering_glossary.aspx	Fluor	Engineering glossary terms

APPENDIX



Old-style graphics load test.



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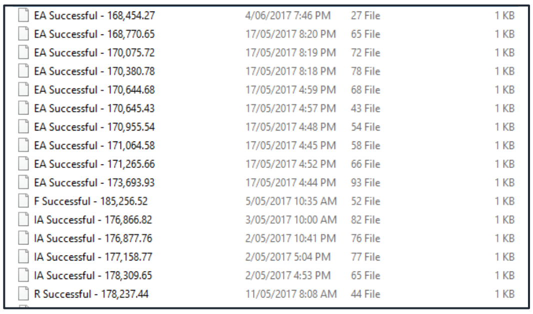

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List of all successful bridges.