2.4.1 Structural Design Activity

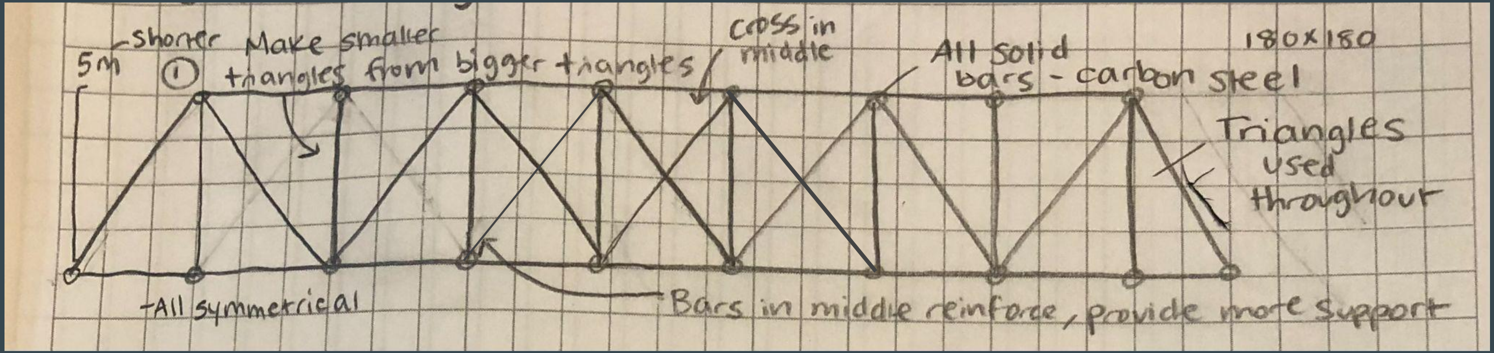
Samiksha Emmaneni

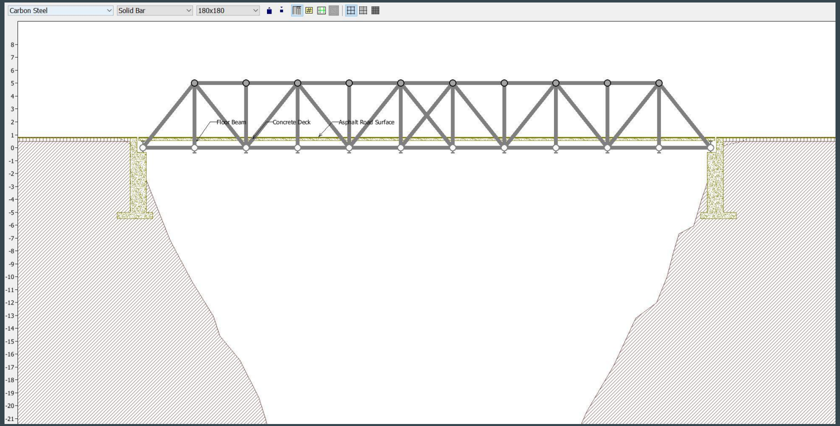
2.4.1 Bridge Design Brief

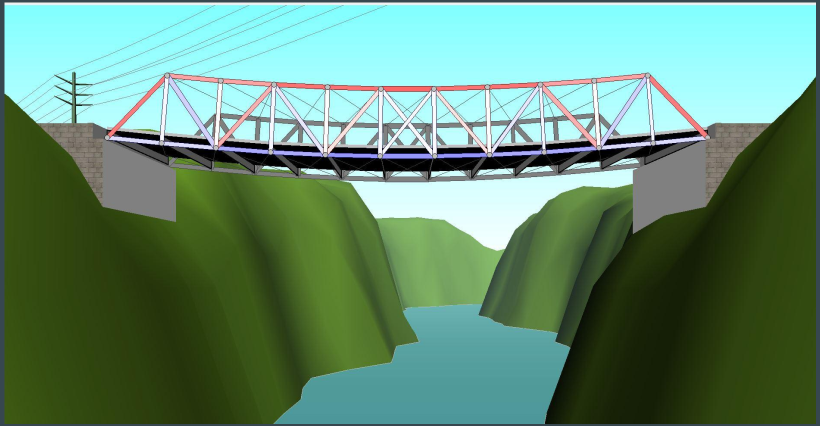
Created by: Samiksha Emmaneni

Client:	Texas Department of Transportation
End User:	The general public
Designer(s):	Samiksha Emmaneni
Problem Statement:	A bridge is to be created utilizing the West Point Bridge Designer software, and is needed to carry the weight of vehicles such as trucks and cars without collapsing over a river bed. It must be durable and cheap for many users to use over a period of time.
Design Statement:	Design, market, test, and mass produce a bridge using the West Point Bridge Designer software, that is cost-effective, reliable, and stable for the general public, specifically for those needing to use a bridge to cross safely.
Criteria & Constraints:	- Must cost less than $400,000 - Bridge must cross the valley at any elevation from water level to 24 meters above water level - Highest point may not exceed an elevation of 32.5 m - Each bridge truss may have no more than 50 joints and 120 members - Bridge deck must be 10 m wide - Materials used include only carbon steel; high-strength, low alloy steel; or quenched and tempered steel - Members of the bridge can only be hollow or solid - Must carry all forces of the concrete deck, members, main truss, steel floor beams, and vehicles - Must have a flat, reinforced concrete deck

Brainstorming Sketch 1

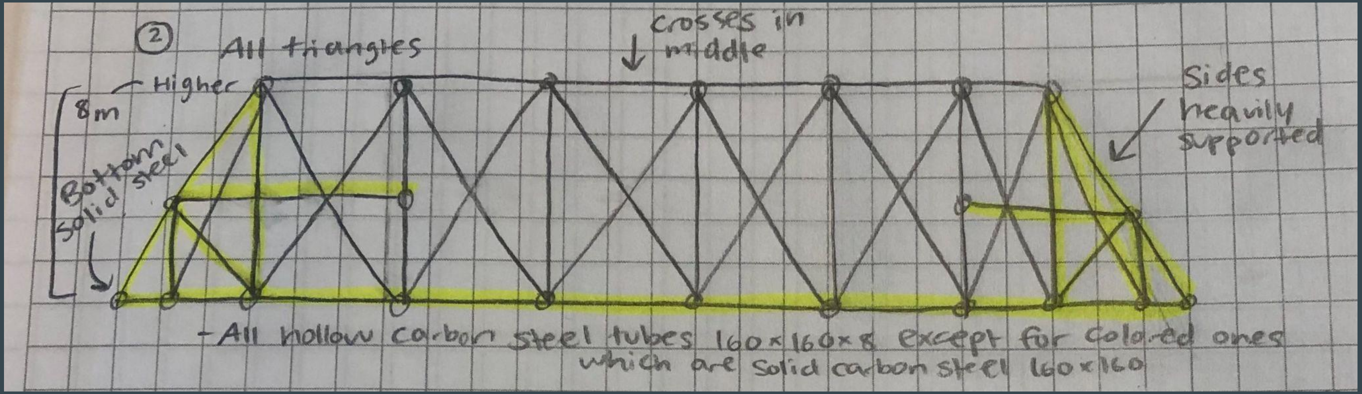


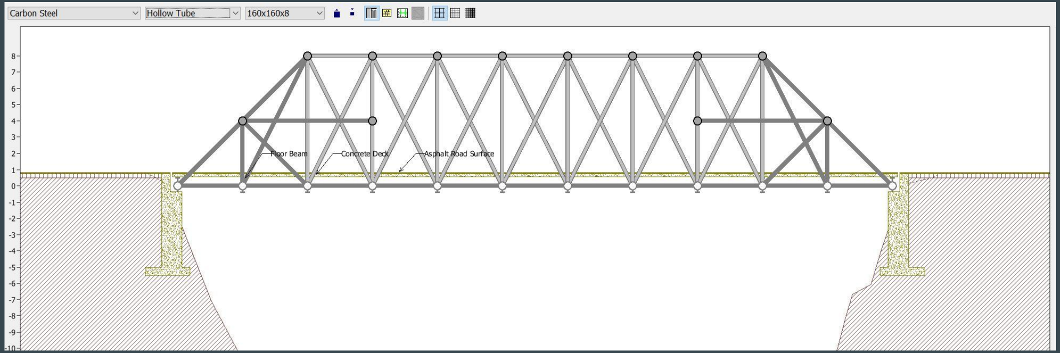


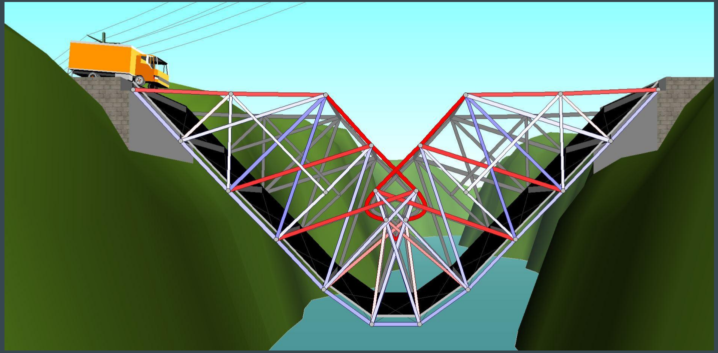


This is the first sketch I created. I decided to go with all solid carbon steel bars that were 180x180. I wanted the bridge to be symmetrical as well so I added a cross in the middle. The entire bridge consists of triangles within triangles, and the reason I did this was because I know that most bridges use this strategy to create more support for the forces and weight they're holding. I decided to test my bridge as well, and as you can see it did work. However, it was far too expensive since they were all solid, thick bars. I also decided to create a bridge that was short in height because I thought it would make it stronger, but this was just an assumption.

Brainstorming Sketch 2

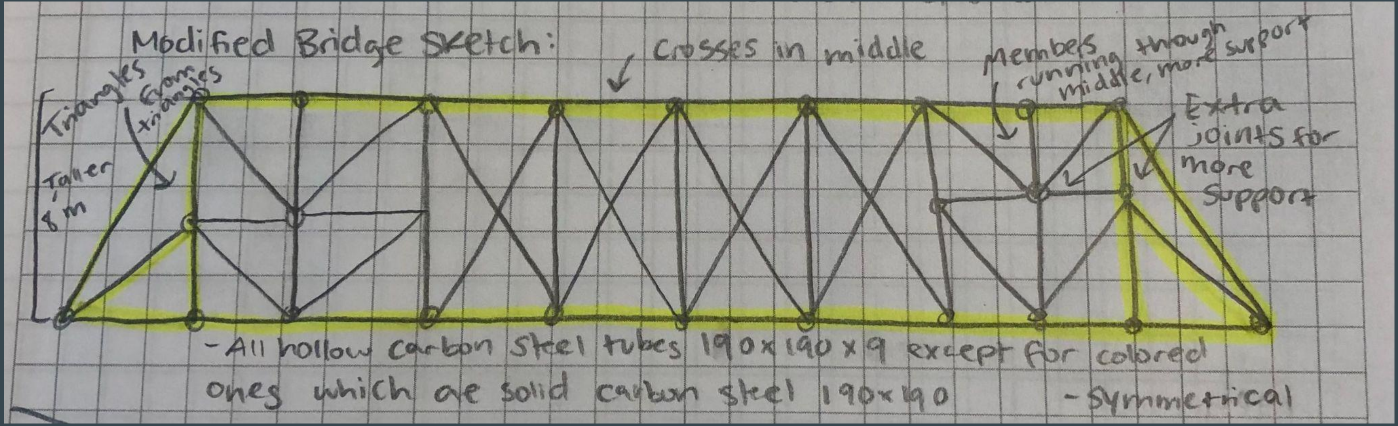


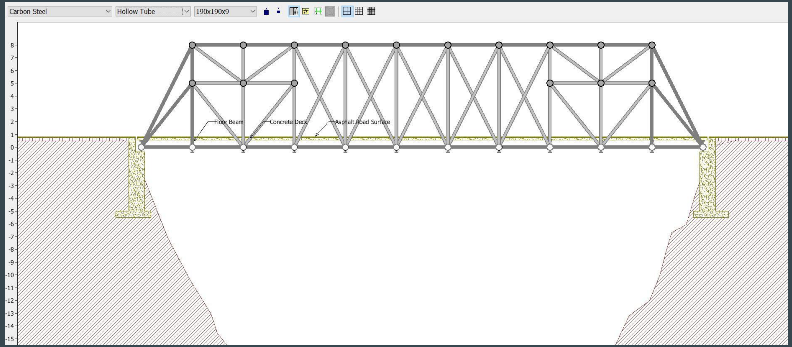




For my second sketch, I decided to approach this a little differently. I liked the idea of the crosses in the middle because I just thought it made it even and balanced. However, I wanted to try adding both hollow and solid carbon steel bars. I decided to go with 160x160 bars and this time I made it taller because I wanted to mess with the height. I also decided to add some extra joints as well because I thought it would help to create more support and make the overall structure more stable. I decided to create the bottom and the sides of the bridge using the solid carbon steel bars. However, when I tried to test my bridge out, it collapsed in the center because of the tension in the top bars. That's when I realized that it would be better to make all the bars surrounding the bridge solid and not hollow.

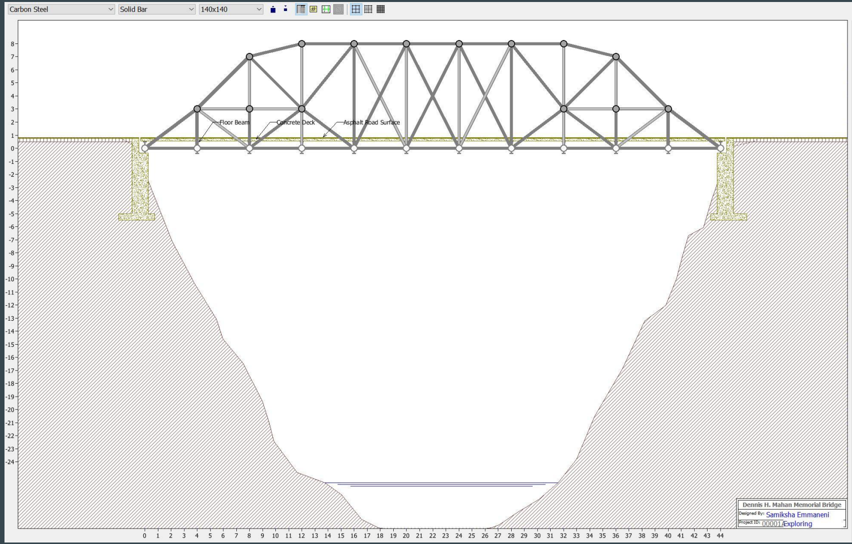
Modified Sketch

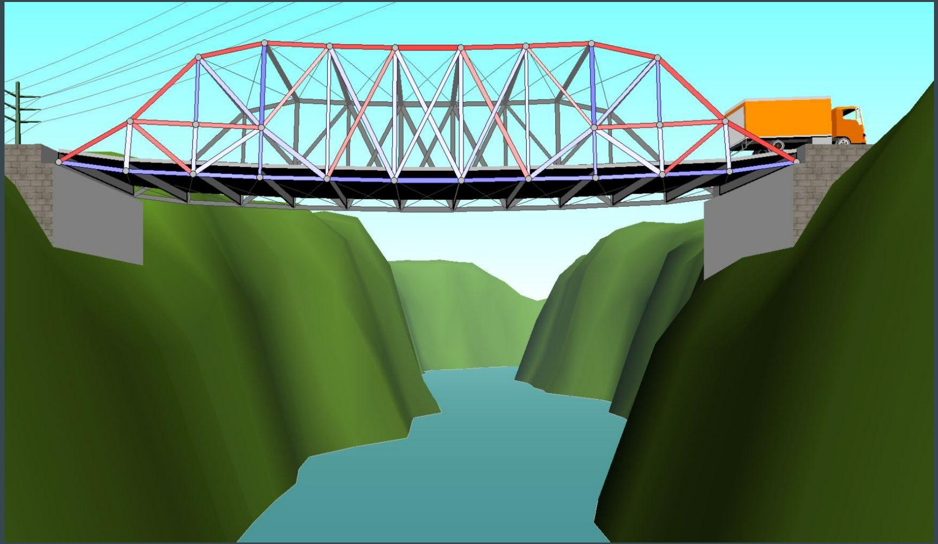




For my modified sketch, I decided to include features that were present in both of my brainstorming sketches. I included the crosses in the middle and added more members to the sides of the bridge to add more support. Learning from my previous mistakes, I decided to add more support at the top and around the bridge by making all of the outer bars solid carbon steel 190x190. I decided to keep the hollow bars in the middle to prevent unnecessary expenses. I decided to go with a design that was taller so that I could add more members in between for more stability. When I tested this design out, I noticed that the members at the end went through a lot of tension, so I realized that I would need to add more support there.

Final Bridge Design





This is the final design I went with. I was really happy with the way this turned out, especially since I was able to incorporate all the different features from my previous sketches. I did make some changes which were to make the bridge more arch shaped, add more members to the sides, and make a few of the middle members solid carbon steel instead of hollow carbon steel. The reason I decided to do this was because in order to ensure that the sides of the bridge weren't undergoing lots of tension, I had to make them thicker and provide more joints for member support. By doing this, the middle area underwent some tension. To fix this, I decided to make the bars that were undergoing the tension in the middle, solid. This strategy worked and I managed to stay under the budget of $400,000 because I made sure to use the minimum thickness needed. The entire bridge is symmetrical and uses triangles. I decided to do this because I wanted my bridge to look more like those seen in real life.

Data collected from Bridge Design- Load Test Results

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	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	2219.18	4655.00	OK
2	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	2219.18	4655.00	OK
3	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	1786.21	4655.00	OK
4	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	1786.21	4655.00	OK
5	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	2422.01	4655.00	OK
6	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	2344.62	4655.00	OK
7	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	2423.33	4655.00	OK
8	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	1757.48	4655.00	OK
9	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	1757.48	4655.00	OK
10	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	2180.53	4655.00	OK
11	CS	Bar	140	4.00	98.97	0.00	2633.62	OK	2180.53	4655.00	OK
12	CS	Bar	160	5.00	108.25	2773.97	3108.78	OK	0.00	6080.00	OK
13	CS	Tube	140	5.00	91.96	529.11	536.93	OK	0.00	884.45	OK
14	CS	Bar	160	3.00	64.95	0.00	4613.21	OK	628.87	6080.00	OK
15	CS	Bar	140	5.00	123.72	0.00	1970.68	OK	779.78	4655.00	OK
16	CS	Bar	140	5.00	123.72	0.00	1970.68	OK	495.70	4655.00	OK
17	CS	Tube	140	3.00	55.18	0.00	713.86	OK	625.46	884.45	OK
18	CS	Tube	140	5.00	91.96	529.40	536.93	OK	0.00	884.45	OK
19	CS	Bar	160	5.00	108.25	2725.66	3108.78	OK	0.00	6080.00	OK
20	CS	Bar	160	3.00	64.95	0.00	4613.21	OK	628.87	6080.00	OK
21	CS	Bar	140	5.00	123.72	0.00	1970.68	OK	439.98	4655.00	OK
22	CS	Bar	140	5.00	123.72	0.00	1970.68	OK	821.48	4655.00	OK
23	CS	Tube	140	3.00	55.18	0.00	713.86	OK	625.46	884.45	OK
24	CS	Bar	140	8.00	197.95	3.51	782.00	OK	221.01	4655.00	OK
25	CS	Bar	140	6.40	158.44	411.72	1220.68	OK	0.00	4655.00	OK
26	CS	Bar	140	6.40	158.44	416.80	1220.68	OK	0.00	4655.00	OK
27	CS	Bar	140	8.00	197.95	13.63	782.00	OK	237.84	4655.00	OK
28	CS	Bar	160	5.66	122.47	2181.04	2615.76	OK	0.00	6080.00	OK
29	CS	Bar	140	5.66	139.97	0.00	1564.00	OK	884.41	4655.00	OK
30	CS	Tube	140	4.00	73.57	462.81	630.23	OK	0.00	884.45	OK
31	CS	Tube	150	4.00	68.44	462.81	704.11	OK	0.00	950.95	OK
32	CS	Tube	150	4.00	68.44	0.00	704.11	OK	529.36	950.95	OK
33	CS	Bar	140	5.66	139.97	0.00	1564.00	OK	882.79	4655.00	OK
34	CS	Bar	160	5.66	122.47	2161.29	2615.76	OK	0.00	6080.00	OK
35	CS	Tube	150	4.00	68.44	434.48	704.11	OK	0.00	950.95	OK
36	CS	Tube	140	4.00	73.57	434.48	630.23	OK	0.00	884.45	OK
37	CS	Tube	150	4.00	68.44	0.00	704.11	OK	532.27	950.95	OK
38	CS	Bar	150	3.00	69.28	0.00	3932.43	OK	523.42	5343.75	OK
39	CS	Bar	150	3.00	69.28	0.00	3932.43	OK	526.32	5343.75	OK
40	CS	Bar	140	4.12	102.02	2206.20	2550.11	OK	0.00	4655.00	OK
41	CS	Bar	140	4.00	98.97	2140.32	2633.62	OK	0.00	4655.00	OK
42	CS	Bar	140	4.00	98.97	2120.32	2633.62	OK	0.00	4655.00	OK
43	CS	Bar	140	4.12	102.02	2185.58	2550.11	OK	0.00	4655.00	OK
44	CS	Tube	140	5.00	91.96	0.00	536.93	OK	525.84	884.45	OK
45	CS	Tube	140	5.00	91.96	0.00	536.93	OK	520.84	884.45	OK
46	CS	Bar	140	4.00	98.97	2376.83	2633.62	OK	0.00	4655.00	OK
47	CS	Bar	140	4.00	98.97	2603.31	2633.62	OK	0.00	4655.00	OK
48	CS	Bar	140	4.00	98.97	2369.53	2633.62	OK	0.00	4655.00	OK
49	CS	Tube	140	8.00	147.13	0.00	268.93	OK	129.73	884.45	OK
50	CS	Tube	140	8.00	147.13	10.61	268.93	OK	129.83	884.45	OK
51	CS	Bar	140	8.94	221.31	423.74	625.60	OK	0.00	4655.00	OK
52	CS	Bar	140	8.94	221.31	0.00	625.60	OK	383.50	4655.00	OK
53	CS	Tube	140	8.94	164.50	0.00	215.14	OK	197.20	884.45	OK
54	CS	Bar	140	8.94	221.31	417.47	625.60	OK	0.00	4655.00	OK
55	CS	Bar	140	8.94	221.31	0.00	625.60	OK	370.24	4655.00	OK
56	CS	Tube	140	8.94	164.50	0.00	215.14	OK	183.83	884.45	OK

Data collected from Bridge Design- Cost Calculations Report

Cost Calculations Report

Type of Cost	Item	Cost Calculation	Cost
Material Cost (M)	Carbon Steel Solid Bar	(32419.2 kg) x ($4.30 per kg) x (2 Trusses) =	$278,805.41
	Carbon Steel Hollow Tube	(2487.5 kg) x ($6.30 per kg) x (2 Trusses) =	$31,342.69
Connection Cost (C)		(26 Joints) x (400.0 per joint) x (2 Trusses) =	$20,800.00
Product Cost (P)	32 - 140x140 mm Carbon Steel Bar	($1,000.00 per Product) =	$1,000.00
	12 - 140x140x7 mm Carbon Steel Tube	($1,000.00 per Product) =	$1,000.00
	2 - 150x150 mm Carbon Steel Bar	($1,000.00 per Product) =	$1,000.00
	4 - 150x150x7 mm Carbon Steel Tube	($1,000.00 per Product) =	$1,000.00
	6 - 160x160 mm Carbon Steel Bar	($1,000.00 per Product) =	$1,000.00
Site Cost (S)	Deck Cost	(11 4-meter panels) x ($4,700.00 per panel) =	$51,700.00
	Excavation Cost	(0 cubic meters) x ($1.00 per cubic meter) =	$0.00
	Abutment Cost	(2 standard abutments) x ($5,750.00 per abutment) =	$11,500.00
	Pier Cost	No pier =	$0.00
	Cable Anchorage Cost	No anchorages =	$0.00
Total Cost	**M + C + P + S**	**$310,148.11 + $20,800.00 + $5,000.00 + $63,200.00 =**	**$399,148.11**

As you can see, I managed to keep the cost under $400,000- just barely under the budget.

Reflection Questions

Learning Target: The learning target for this activity was to figure out how to design a bridge that would fit certain realistic constraints and requirements using the West Point Bridge Designer software. We had to identify the problem to be solved, and generate different solutions using our creativity and knowledge of trusses.

Reflection: This activity really allowed for me to realize just how complicated designing structures, specifically bridges, are. There's a lot of thought that goes into it, and it's much more restricted when there are budgets. However, from trial and error, I was able to take note of the key features put into stabilizing a bridge, such as where the thickest members should be, or when it's necessary to make a member solid or hollow.

What I need to work on: I need to work on stepping outside of my comfort zone when designing any structures. I tend to mindlessly lean towards designs I see in real life just because it's what seems the most reasonable to me. But now looking at my bridge, I think that if I had made mine a bit more unique, I could have made one a lot more cheaper. My cost was so close to the budget, and that made me realize that while certain designs may work, depending on the different situations and circumstances, they may need to change significantly.

Reflection Questions

Identify the characteristics of your bridge design. My bridge design is 8 meters tall and incorporates only triangles. The outer members are the ones that are the strongest, as they're thicker and solid. I included crosses in the middle of my bridge to make it more balanced and symmetrical since the sides of it were already triangles angled towards their associated side. I made it entire out of carbon-steel using both hollow and solid members. The middle used mainly hollow bars with a few solid ones, and the outermost ones used mainly solid bars.

Why did you make it with the chosen materials? I made it all out of carbon-steel because I wanted the material to stay the same. I went with carbon-steel because it had the cheapest prices, and my goal was to ensure that the total cost stayed below $400,000.

What was the biggest change you made from your initial design? The biggest change I made was to add solid bars to all the surrounding bars, and create and inside with mostly hollow bars. This was my biggest change because initially I didn't know if it mattered or not, and decided to either use just one type of bar or less of one and more than the other. Looking at my final design, I was able to make it somewhat balanced and this worked out because it remained stable.

What new concepts or learning took place throughout the unit 2 section over trusses and structural design that you feel made the most impact on you personally? Concepts I learned over the unit 2 section included things such as calculating/finding the stress, strain, tension, and compression of different objects within structures. This had the most impact on me personally because when I now analyze any structure, I can try to assume areas where the most tension or compression may take place, depending on where the force is. For example, if there's a force acting on a bridge, the members in the most tension are likely to be the ones at the bottom, while the ones at the top may face the most compression. Additionally, by knowing how to calculate stress and strain, it makes it much easier for me to understand how much thought and calculations are involved when designing any structure. It's essential to calculate these things to ensure that the structure is feasible and that the members work within it without fail.