TAYLOR'S UNIVERSITY
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BUILDING STRUCTURE
ARC 2523

PROJECT 1:
FETTUCCINE TRUSS BRIDGE

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1.0 INTRODUCTION

1.1 PROJECT INTENTION

The aim of this project is for us to construct perfect truss bridges that are made out of fettuccine in order for us to evaluate, explore and improve on the understanding of compression and tensile strength of construction materials and also the understanding of force distribution in a truss. With these results we could apply the understandings, able to evaluate and identify tension and compression members in a truss structure and also explore different arrangements of members in a truss structure.

1.2 PROJECT REQUIREMENTS

The requirements are as followed:

- Bridge made out of fettuccine.
- A perfect truss bridge.
- Clear span of bridge is 350 millimeters.
- Maximum weight of bridge is 70 grams.
- An efficient truss bridge.

1.3 WORKING SCHEDULE

DATE	TASKS
9^{TH} April	Buy material and prepare equipment.
10^{th} April	Test compression/tensile of different brands.
17^{th} April	Construct different types of perfect truss bridge.
20^{th} April	Test height, truss member arrangements etc.
24^{th} April	Construct and test bridge.
30^{th} April	Construct and test bridge.
1^{st} May	Construct and test bridge.
7^{th} May	Construct and test bridge + Report.
8^{th} May	Construct and test bridge + Report.
9^{th} May	Test on final bridge.

Table 1.3.1: Working schedule.

2.0 METHODOLOGIES

2.1 PRECEDENT STUDY

To research about a perfect Warren truss bridge with vertical members with sources taken from books and the Internet on the details, construction methods, force distributions, connections, arrangements of truss members and orientation of each members. This plays an important role for us to apply and improve the construction methods to construct the most efficient bridge as possible.

2.2 CONSTRUCTION OF TRUSS BRIDGE

PHASE 1: Fettuccine Strength Test

We started off by identifying the compression and tension strengths of different brands of fettuccine. This varies because of their thickness and quality. After that, we tested different variables that are length of fettuccine, number of layers, orientation of fettuccine (vertical and horizontal).

PHASE 2: Adhesive Test

One of the most important things of a strong structure is the connection. We tested out different types of adhesives to identify which has the strongest bond.

PHASE 3: Model Making

We constructed a few types of perfect truss bridges that was given in the project brief and chose the one with the strongest structure by applying compression force and measuring it. Afterwards, we designed with different arrangements of truss members, heights and layers of members to achieve a strong structure.

PHASE 4: Model Testing

Finished models are applied with hanging load in the center of the truss bridge. We started with a 500g load and added 500g subsequently after every 10 seconds. We identified the weaknesses and recorded the data.

3.0 PRECEDENT STUDY

TAYLOR - SOUTHGATE BRIDGE

Figure 3.0.1: Taylor-Southgate Bridge, Ohio.

Taylor – Southgate Bridge is a continuous truss bridge, which was constructed in 1995. The main span of the bridge is 260m and has a total span of 560m. It spans across the Ohio River connecting Newport, Kentucky and Cincinnati, Ohio, which carries Route 27.

Some regard this bridge, which was a replacement for the Cincinnati-Newport Bridge built by Samuel Bigstaff, as a little too plain in its design for a major urban bridge, especially considering many cities today are opting for a more elegant design, such as a cable stayed bridge.

The bridge is named for the families of James Taylor, Jr. and Richard Southgate, two important early settlers of Newport. Richard was the father of William Wright Southgate, a pre Civil War Congressman from northern Kentucky.

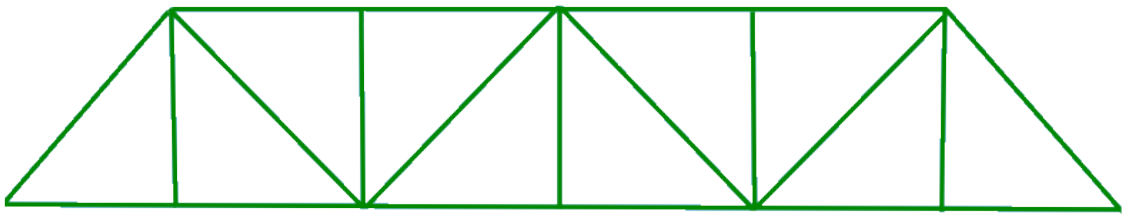


Table 3.0.2: Warren truss bridge with vertical members.

Warren truss structure is one of the most popular bridge designs due to the fact that it uses equilateral triangles to spread out the dead and live loads on the bridge. Equilateral triangles minimize the forces to be in only compression and tension form. With the Warren truss structure, it can switch a live load from compression force to tension force. This frequently happens at the members at the center of the bridge itself.

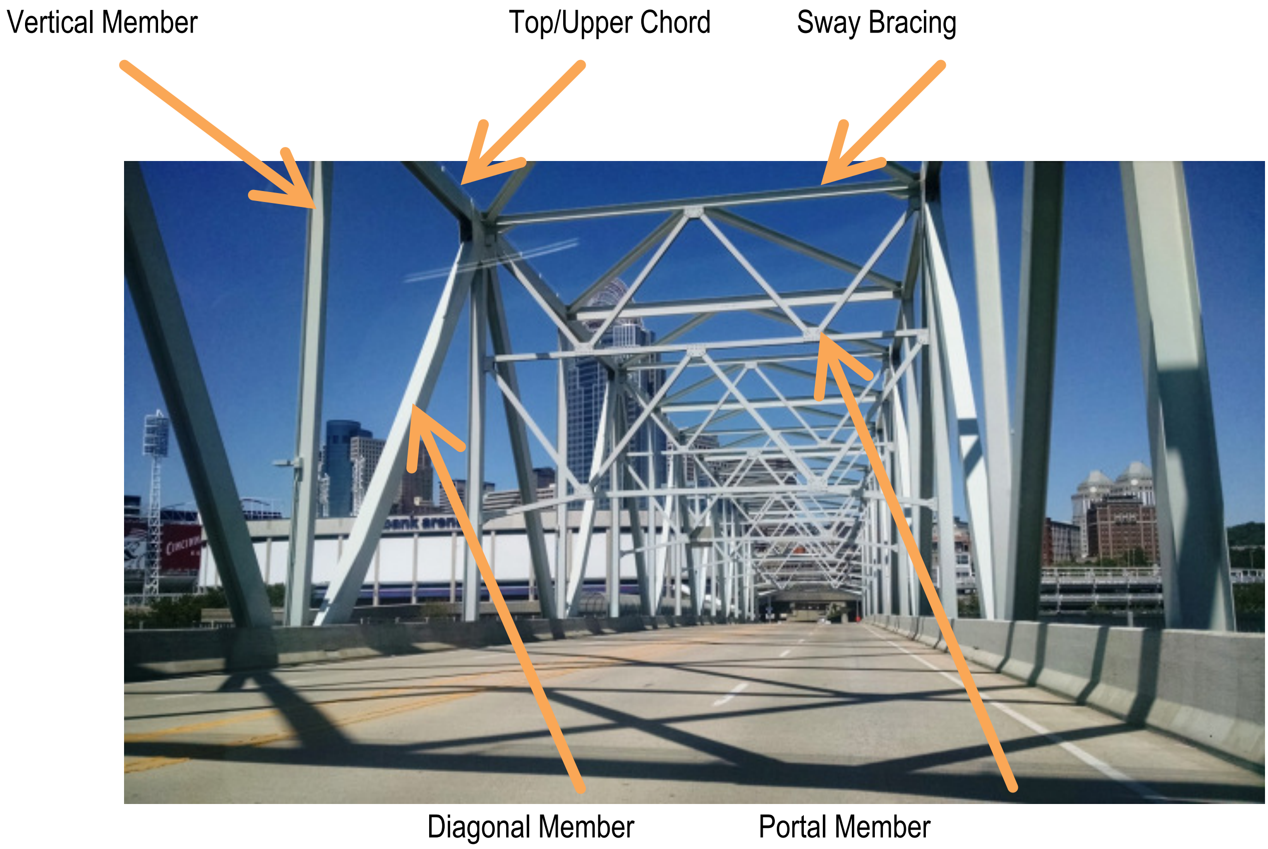


Table 3.0.3: Warren Truss Bridge components.

4.0 EQUIPMENT & MATERIAL

4.1 FETTUCCINE STUDY

 4.1.1: *Kimball* Fettuccine	 4.1.2: *San Remo* Fettuccine

1. We have selected two different brands of fettuccines that are shown in **Figure 4.1.1 and 4.1.2** to carry out the material load testing and decided to use the strongest one. We identified that *San Remo* is the strongest amongst *Kimball*. We tested both orientations, which were vertical and horizontal. The results are recorded in the tables below.

Figure 4.1.3: Vertical side.

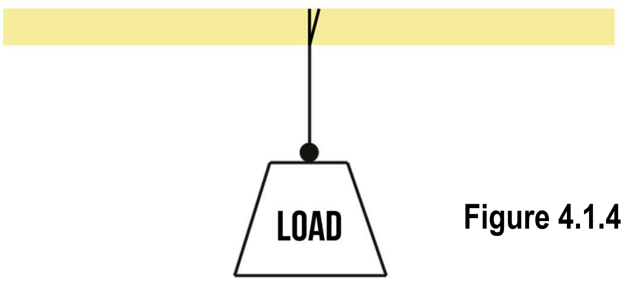
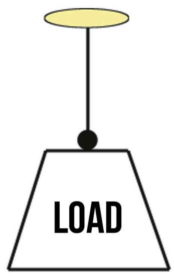


Figure 4.1.4: Horizontal side.



Fettuccine Load Testing Results

√	Didn't break
X	Break

Legend

Kimball Fettuccine (Horizontal)

Load / Layers	100g	200g	300g	400g	500g	600g
One	√	√	X	X	X	X
Two	√	√	√	X	X	X
Three	√	√	√	√	√	X

Table 4.1.5: Load testing results of _Kimball_ fettuccine on horizontal side.

Kimball Fettuccine (Vertical)

Load / Layers	100g	200g	300g	400g	500g	600g	700g	800g	900g	1000g
One	√	√	√	√	X	X	X	X	X	X
Two	√	√	√	√	√	√	√	√	√	√
Three	√	√	√	√	√	√	√	√	√	√
I-Beam	√	√	√	√	√	√	√	√	√	√

Table 4.1.6: Load testing results of _Kimball_ fettuccine on vertical side.

San Remo Fettuccine (Horizontal)

Load / Layers	100g	200g	300g	400g	500g	600g
One	√	√	X	X	X	X
Two	√	√	√	√	X	X
Three	√	√	√	√	√	√

Table 4.1.7: Load testing results of *San Remo* fettuccine on horizontal side.

***San Remo* Fettuccine (Vertical)**

Load / Layers	100g	200g	300g	400g	500g	600g	700g	800g	900g	1000g
One	√	√	√	√	√	X	X	X	X	X
Two	√	√	√	√	√	√	√	√	√	√
Three	√	√	√	√	√	√	√	√	√	√
I-Beam	√	√	√	√	√	√	√	√	√	√

Table 4.1.8: Load testing results of *San Remo* fettuccine on vertical side.

Results in the tables show that ***San Remo*** is much stronger compared to ***Kimball*** due to the fact that it's more solid and thicker.

Also, vertical members are stronger than horizontal because the space of load distribution is more. We have used horizontal side for members that are facing most loads so it'll achieve load equilibrium.

4.2 ADHESIVE TYPES

TYPE	PROS	CONS
 ACRYLIC NAIL GLUE	- Strong bond. - Fills up gap. - Dries fast.	- Creates lump when dry. - Heavy. - Expensive.
 3 SECOND GLUE	- Strong bond. - Dries fast. - Uses little. - Clean joints.	- Cannot use twice - Creates lump when dry.
 UHU GLUE	- Easy to use. - Flexible connection.	- Messy. - Creates lumps. - Long time to dry.

Table 4.2.1: Pros and cons of different types of adhesives.

As a conclusion from the **table 4.2.1**, we used both acrylic nail and 3-second glue because they have the strongest bonds amongst the three.

4.3 EQUIPMENT

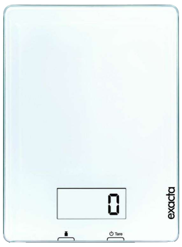
EQUIPMENT	DESCRIPTION
 CUTTING KNIFE	• Can cut the fettuccine precisely and accurately.
 METAL RULER	• To indicate and guide for cutting the fettuccine.
 S-HOOK	• Use to connect the load and fettuccine.
 DIGITAL SCALE	• Define the weight of the bridge.
 CANVAS BAG	• Use to put bottles as load for the bridge.

Table 4.3.1: Equipment that we used for the bridge truss test.

5.0 BRIDGE TESTING / ANALYSIS

5.1 DETAILED PROGRESS OF BRIDGE CONSTRUCTION

Testing the strength of different types of bridge structure

DATE	WORK PROGRESS
20st April	-Testing and comparing the strength of different types of bridge structure. Eg. Pratt , Waddell and Warren
29th April	-Testing on different ways of joining the fettuccines. -Trying on various types of adhesive to test the strength . -Experiment on which way and how many layers of fettuccine to use in beams is the strongest.
30th April	-Testing on first , second and third bridge
1st May	-Continue to experiment the bridges with different dimension such as different height, Width and length.
6th May	-Improve the strength of bridges by changing the methods of joining the fettuccine and add by adding layers to the beams.
7th May	-Continue in testing the bridges with load.
8th May	-Refining the final bridge.
9th May	Final submission and load testing of bridge.

PROGRESS ON CONSTRUCTING BRIDGE

Select the perfect fettuccine.

In order to have a stable bridge, is to select the perfect fettuccine. In terms of perfect, its referring to the straight and untwisted one.

Workmanship

The measurement for each cut section fettuccine has to be accurate to be able to get the right dimension. Connecting , attaching two cut fettuccine end together plays a very important role in this construction. If connection between two fettuccine is not secure, it will create a weak beam which can break easily.

Create strong beams

Throughout the experiments, we realize just by layering the fettuccine is not strong enough because the fettuccines are in a convex shape. In addition, it is also weak when attaching the vertical member to the beam as the beam does not have a flat surface. Systematically, we flatten the surface by sanding it using sandpaper. This process will create a smooth surface which allows stable connection between the joints.

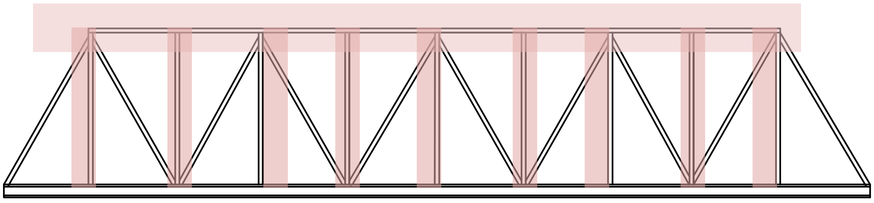
Joining the components of the bridge.

We attached the floor beams and the struts on one side of the truss before sticking two trusses together. After linking the two trusses, we waited for it to dry then seal it up with the acrylic glue. And fill up any gap in the bridge.

MOCK UP TRUSSES

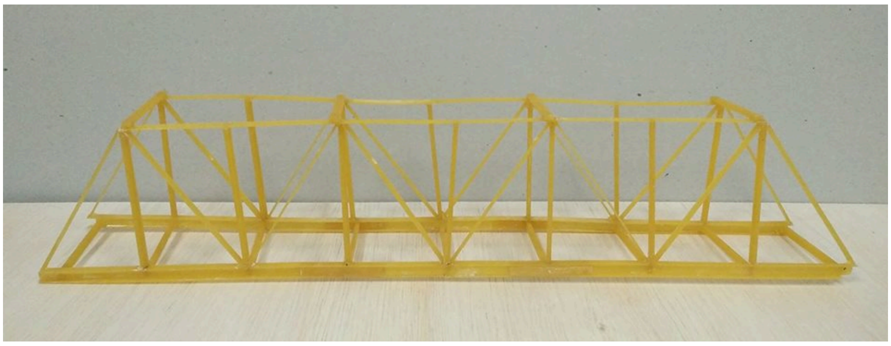
1. Truss 1

Weight	:	75g
Total length	:	40 cm
Total load withstand	:	1500g
Efficiency	:	20 %



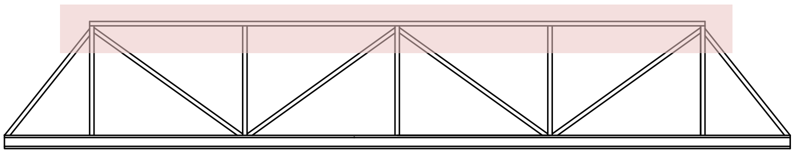
We adopted the classic warren truss with verticals for our first truss model. I beam structure was used as the bottom component of the bridge. The vertical members of the bridge was doubled, while the slanted members remained as single layers. The middle components were also doubled, however no additional structures were added to the center part of the bridge.

When tested, the structure started to sway when load is applied, and the top members started to bend. The entire structure then collapsed after 2kg of load was applied. We've identified that the problem was that the single vertical members were unable to support the entire structure, and the double layer members in the center was not strong enough to withstand the load. The I-beam at the bottom, helped a lot in strengthening the entire structure. However, the weight of the bridge itself exceeded the limit, possibly due to the number of sections.



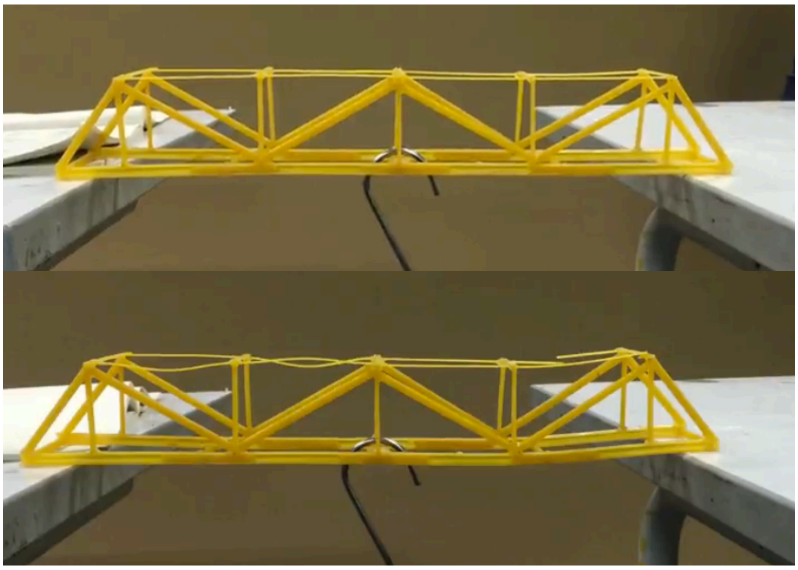
2. Truss 2

Weight	:	62 g
Total length	:	36 cm
Total load withstand	:	2500g
Efficiency	:	40 %



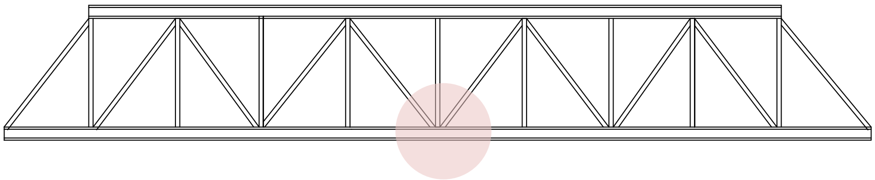
Based on the first mock up truss that we did, we have made several amendments to our second structure. We reduced the height of the structure from 7 cm to 5 cm, and we doubled up all of the vertical member supporting the structure. The bottom structure remained as an I beam, but we also I beam-ed the center of the structure, so it is able to withstand more load. Besides that, we also tried a different way of joining the members.

When tested, we noticed that middle structure of the bridge did not break. However, the upper part of the structure started to drastically bend. It then slowly started to crack, until it finally collapsed. The reduced height of the structure helped in increasing it's stability, and the I beam center also helped to withstand more load.



3. Truss 3

Weight	:	65 g
Total length	:	40 cm
Total load withstand	:	5000 g
Efficiency	:	76 %

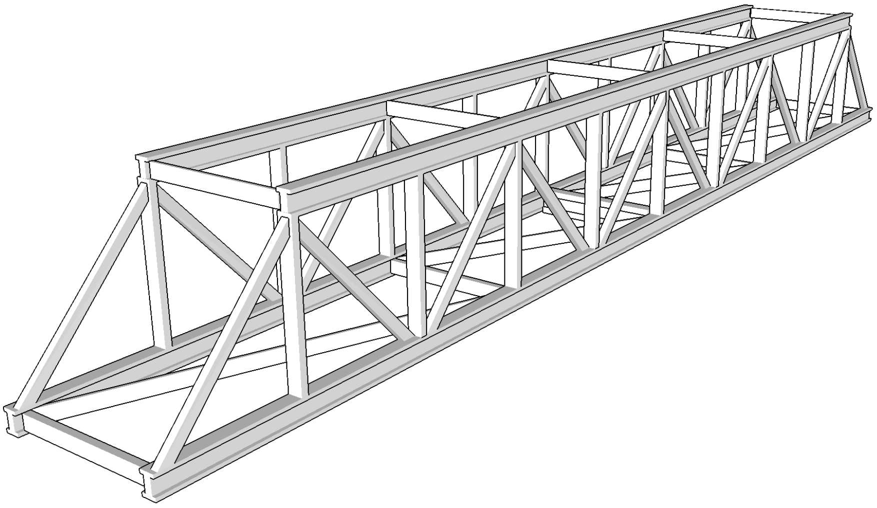


From the previous structure, we've analyzed that the top beam played an important role in anchoring the structure. Therefore, we've decided to I beam the bottom, as well as the top in order the stabilize the structure. We also added additional trusses in the center of the structure to support the middle component. Besides that, we also increased the number of sections from the previous bridge, to increase it's strength. Another problem we noticed from the previous structure was it's poor joints. The glue that we used was unable to bond the joins properly. We then decided to use two layers of glue. Superglue was used to connect the components together, and another layer of Acrylic glue to seal the entire structure.

When tested, we noticed that the entire structure was in tact for the most part. No swaying was detected and very little bents was noticeable. When it reached its maximum load, only the center member broke, while the entire structure was still in place. We concluded that the I-beam structure on the upper part of the bridge played an important role in stabilizing the structure. The acrylic glue also helped in strengthening the bonds of the bridge.

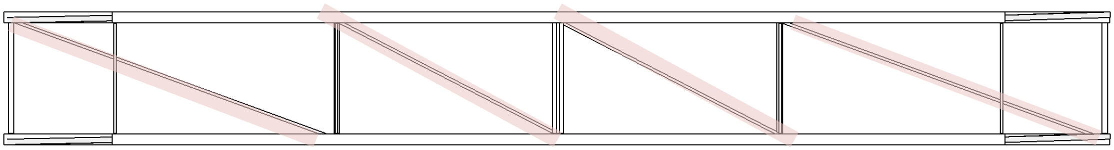
4. Final Bridge Testing

Weight	:	74 g
Total length	:	40 cm
Total load withstand	:	12100 g
Efficiency	:	163 %



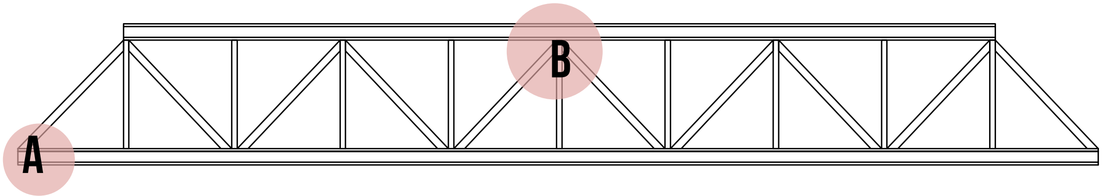
Based on all of the tests we have made, we have decided to use the Warren truss with vertical structure as our final model. We made amendments from our previous structures in order for it to have maximum efficiency. First and for most, the height of the bridge itself has been reduced from 5 cm to 4 cm. The reduction of height helps in stabilizing the structure even more. Besides that, we stuck with the concept of applying I- beam structures to both bottom and top members. We did not double the layers of the slanted members, as we found out that it did not affect the efficiency of the bridge that much. We triples the I-beam at the center in order for it to withstand the most load. Laslty, we sealed the entire structure with the acrylic glue in order to properly hold everything in place.

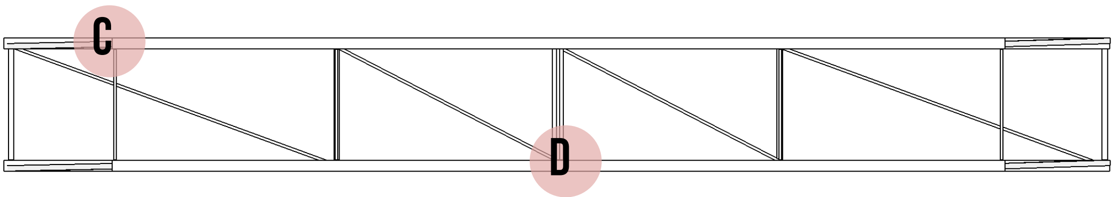
Addition of Members



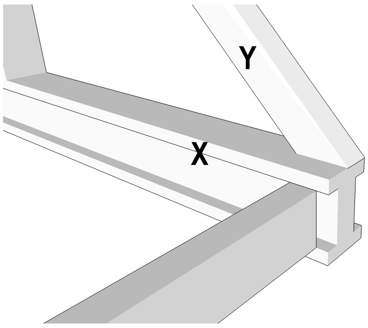
Based on all of our failed structures, we've realized that there is not enough support on the middle member. By adding diagonal members to support both ends of the middle member, we hoped that it would be able to withstand more load.

Joint Analysis



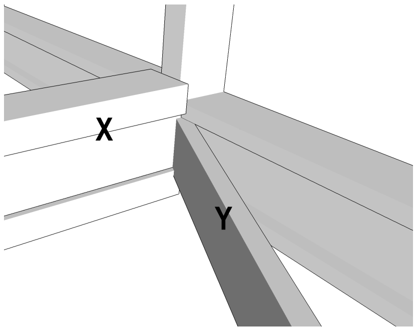


JOINT A

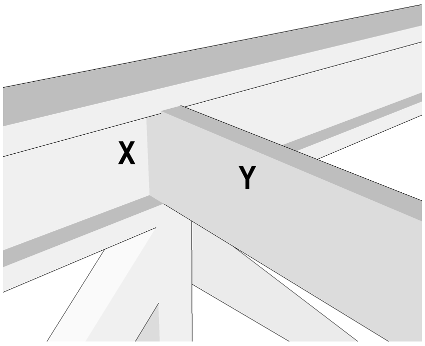


Members X and Y must be in full contact, in order to avoid slipping and allowing the forces to transfer completely between the two members.

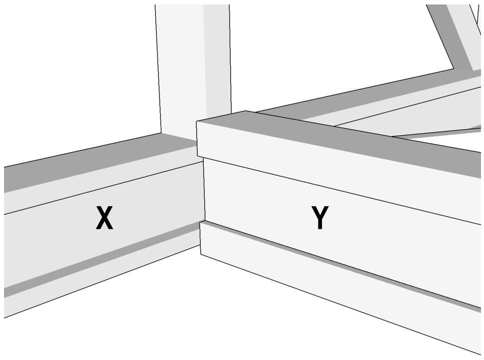
JOINT B



The diagonal member Y helps the support the member X and allows the forces to be distributed equally throughout the structure.



Member Y is inserted into the I beam structure of member X, to ensure that both members are in total contact, so that the forces are distributed evenly.



The center member is the most crucial part of the structure, as the load is concentrated mostly on this member. It must be connected properly to member X, or it wont be able to support it.

Failure Analysis

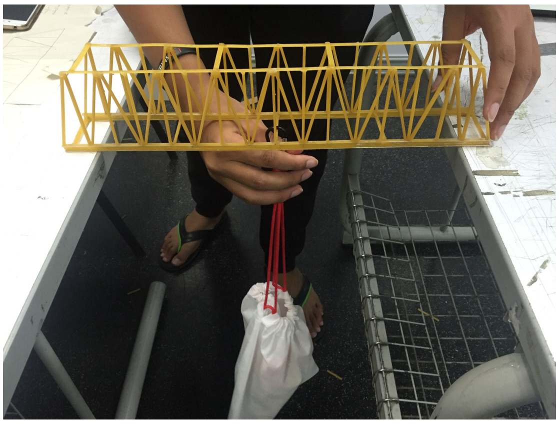
When tested, we noticed that the bridge collapsed due to the way we tied the string on the structure. The amount of surface area that is pulled down by the string affected the entire structure of the bridge. Besides that, we connection between the middle member and the bottom member was not strong enough.

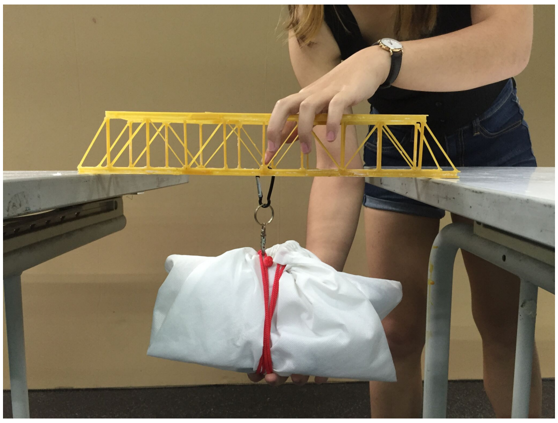
6.0 CONCLUSION

The project has taught us the importance of trial and error. We were told to build a bridge within the weight limit of 70 g, and is able to withstand a load of 5 kq minimum. We have experimented with numerous methods in order to reach the requirement given. Starting from the process of picking the type of fettuccine, to choosing the perfect truss structure. We have also learned that calculation is important in order to determine the effectiveness of your structure, and good workmanship is crucial in order for your structure to withstand the maximum load.

Throughout this project we have constructed 12 bridges in total – and we have learned the importance of manipulating the variables in order to compare the different results. Besides that, we have also learned the proper way of constructing the perfect truss structure via trial and error, and also calculation.

7.0 APPENDIXES





8.0 REFERENCES

1. Boon, G. (2016). Garrett's Bridges » Warren Truss. Garrettsbridges.com. Retrieved 12 May 2016, from http://www.garrettsbridges.com/design/warren-truss/

2. Dillon, A. (2016). Taylor-Southgate Bridge. Bridgehunter.com. Retrieved 9 May 2016, from https://bridgehunter.com/oh/hamilton/taylor-southgate/

3. Frank Griggs, P. (2016). STRUCTURE magazine | The Warren Truss. Structuremag.org. Retrieved 12 May 2016, from http://www.structuremag.org/?p=8715

4. Klopp, R. (1989). Truss bridges. Stuttgart: IRB Verlag.

5. Liew, G. (2016). Presentation, https://issuu.com/gabrielliew/docs/p1?e=12599216/32164044.

6. Merrill, W. (1875). Iron truss bridges for railroads. New York: D. Van Nostrand.

7. Ting, A. (2016). Presentation, http://www.slideshare.net/Adelinetingg/building-structure-project-1-report.

8. Truss Bridge - Facts and Types of Truss Bridges. (2016). Historyofbridges.com. Retrieved 9 May 2016, from http://www.historyofbridges.com/facts-about-bridges/truss-bridge/

9. Truss bridge | engineering. (2016). Encyclopedia Britannica. Retrieved 9 May 2016, from http://global.britannica.com/technology/truss-bridge