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BUILDING STRUCTURES
[ARC 2213]
FETTUCCINE TRUSS BRIDGE ANALYSIS REPORT

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Truss Bridge

FIGURE 2
Different type of trusses

FIGURE I

1.0 INTRODUCTION

1.1 TRUSS INTRODUCTION

Truss is a structure built up to three or more members which are normally considered being pinned and hinged at the joints. The above figure shows different types of trusses. Load applied to the truss is transmitted to joint so that each individual members are in either pure tension or compression.

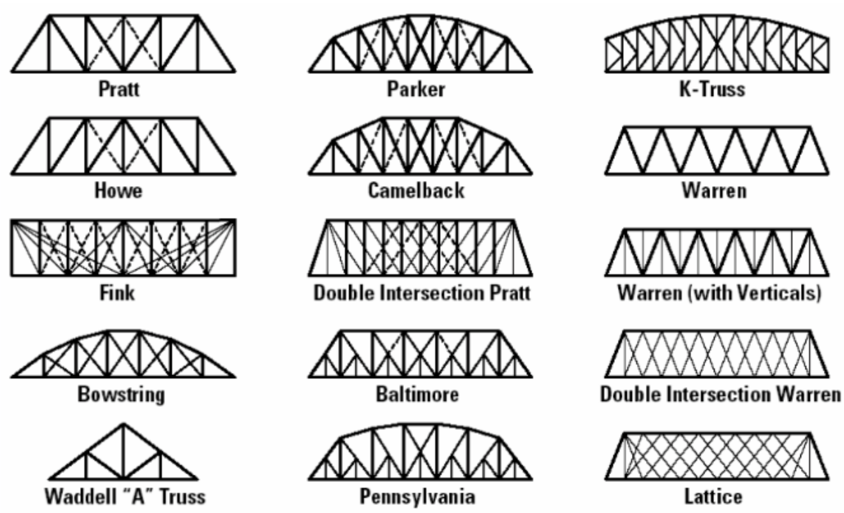


FIGURE 2

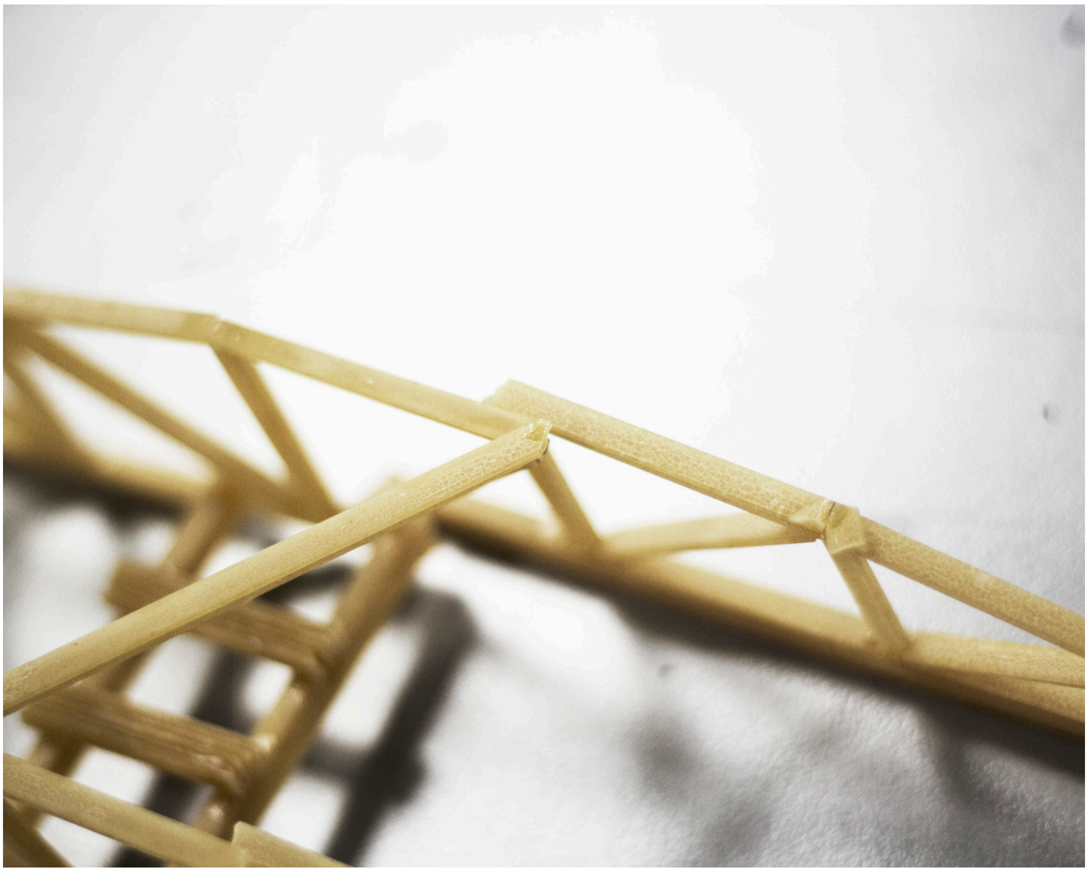


FIGURE 3

FIGURE 3
Fettuccine bridge

1.2 PROJECT INTRODUCTION

This report is a compilation of our understanding and analysis based on precedent studies conducted, construction materials and the design of our truss bridge.

TASK 1
we're each given a case to analyse a truss correctly.

TASK 2
In a group of six, we're required to design and constrcut a fettuccine bridge of 350mm clear span and maximum weight of 80g. These requirements are to be met, or else it may result in reduction of grade. The bridge will be then tested to fail.

Other than aesthetic value, the design of the bridge must be of high efficiency, i.e. using the least material to sustain the higher load. The efficiency of the bridge is given as following;

- *Material strength*

By adopting appropriate method, determine the strength of fettuccine, i.e. tension and compression strength and by knowing the strength of fettuccine, we are able to determine which members to be strengthened.

- *Structural analysis of the truss*

- Perform detailed structural analysis of the truss
- Identify critical members
- Strengthened the critical members if necessary

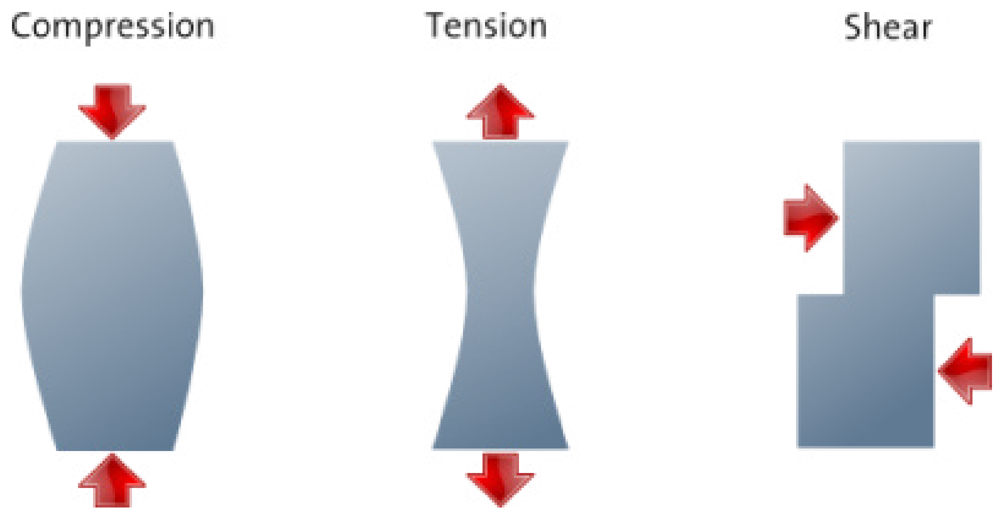


FIGURE 4

FIGURE 4
Diagrams of compression, tension, shear

1.3 PROJECT OBJECTIVE

The aim of this project is to develop our understanding of tension and compressive strength of construction materials, also the force distribution in a truss.

1.4 INTRODUCTION OF TENSION

Tension describes the pulling force exerted by each end of any one-dimensional continuous object, be it a string, rope, cable or wire. The tensile force is focused along the length of an object and pulls uniformly on opposite ends of it.

1.5 INTRODUCTION OF COMPRESSION

Compressive force refers to the capacity of a material in resisting pushing forces that are focused axially. Compressive force can also be defined as the capacity of a structure to withstand loads tend to reduce its size.

FIGURE 5

FIGURE 6

FIGURE 5
Landscape shot of Long Meadow Bridge

FIGURE 6
Trusses of Long Meadow Bridge

FIGURE 7
Tension and compression illustration on Long Meadow Bridge's camelback truss

2.0 PRECEDENT STUDY

2.1 INTRODUCTION: LONG MEADOW BRIDGE

The Long Meadow Bridge was constructed in 1920 using the Camelback through truss system, a variant of the Pratt truss system. It possesses significance under National Register of Historic Places Criterion Cat the state level in the area of Engineering. Built to span the wide overflow of the Minnesota River, the Long Meadow Bridge required the placement of five through trusses to meet this engineering challenge. When constructed, it was the longest steel highway bridge with concrete flooring in the state; today it remains as the state's longest Pratt through truss bridge, and is one of only five bridges using a Camelback through truss system considered historic. Specifically, it is a bridge that exhibits exceptional engineering skill to meet unusual site conditions. The bridge's period of significance is 1920, the date it was completed.

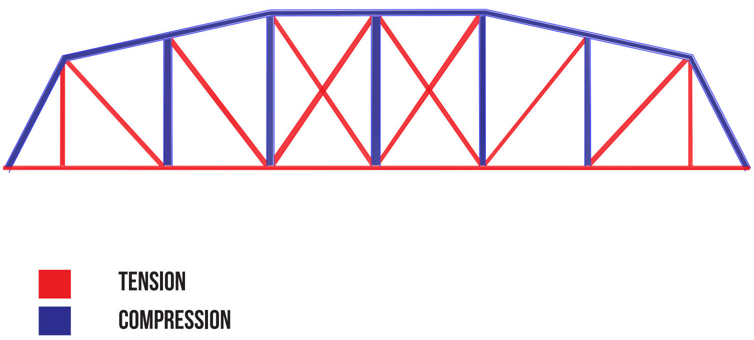


FIGURE 7


FIGURE 8

FIGURE 8
Long Meadow Bridge
Trusses

2.2 STRUCTURAL ELEMENTS

The bridge consists of five Camelback through trusses, each measuring 170 feet in length for a total bridge length of 860 feet, including expansion bearings. The deck is supported by eight steel 1-beam stringers, connected to the web of the steel floor beam girders. Each of the steel trusses is identical, formed by eight panels with riveted connections, and mounted on bearings. Two inward facing channel sections joined by V -lacing form the lower chord, while the upper chord and inclined end posts are composed of back-to-back channel sections joined by a cover plate and lattice lacing. Primary vertical members are formed by pairs of slender channel sections with V-lacing riveted to the outer sides. Diagonal members are fanned by four angle sections tied with flat lattice. Additional counter bracing on the inner panels consist of two angle sections fastened with flat lacing bars. Sway bracing forms an X with an added vertical member connecting the intersection to the lower horizontal member; all members are of angle sections secured by rivets and plates. Two crossing angles comprise both the top and lower lateral bracing. The bridge's portal bracing uses angle sections in alternating diagonals with the end members extending below the horizontal member to join the end posts.

FIGURE 9

Figures above are views of bridge beams at the south end of the structure showing the connection between girders and a stringer at the abutment.

FIGURE 10

Figure on the left are views of the bridge bearings at the south end of the structure, whereas the right shows the southeast bridge bearing.

FIGURE 11

Figures above shows the southwest corner of the structure. Note that the beam in the foreground is riveted to a gusset plate. Riveted construction was common prior to World War II.

FIGURE 12

Figure on the left indicates bridge girder while figure on the right shows a beam made of two parallel members that are cross-braced by small steel straps.

FIGURE 9
Bridge beam of Long Meadow Bridge

FIGURE 10
Bridge bearing of Long Meadow Bridge

FIGURE 11
Riveted construction of Long Meadow Bridge

FIGURE 12
Bridge Girder of Long Meadow Bridge

FIGURE 13

FIGURE 14

FIGURE 15

FIGURE 13
San Remo brand fettuccine

FIGURE 14
Agnesi brand fettuccine

FIGURE 15
Barilla fettuccine

3.0 MATERIALS & EQUIPMENTS

3.1 TYPE OF FETTUCCINE ANALYSIS

As stated in the project brief, fettuccine is the only material that can be used to build the bridge model. Thus, different brands of fettuccine were used to study and test each tensile and compressive strength. Type of fettuccine analysis were conducted before model making.

(i) SAN REMO
- medium rough surface
- medium flexibility
- carries the most weight

(ii) AGNESI
- flexible
- lightweight and thin strips
- carries medium weight

(iii) BARILLA
- lightest and thinnest strip
- very flexible
- carries less weight

FIGURE 16

FIGURE 16
Fettuccine

3.2 TESTING OF FETTUCCINE

3.2.1 STRENGTH OF FETTUCCINE ANALYSIS

As fettuccine is the only material used to build the bridge model, we're required to study and test it's quality and strength before making the model to ensure minimal construction material and lighter weight construction are used to achieve high efficiency and achieve high level of aesthetic value.

Properties of fettuccine

Brittle thus strong under tension but has low compression strength
Thickness: 1mm
Width: 4mm
Ultimate tensile strength: 2000psi
Stiffness (Young's Module) E: 10,000,000 psi
E= stress/strain

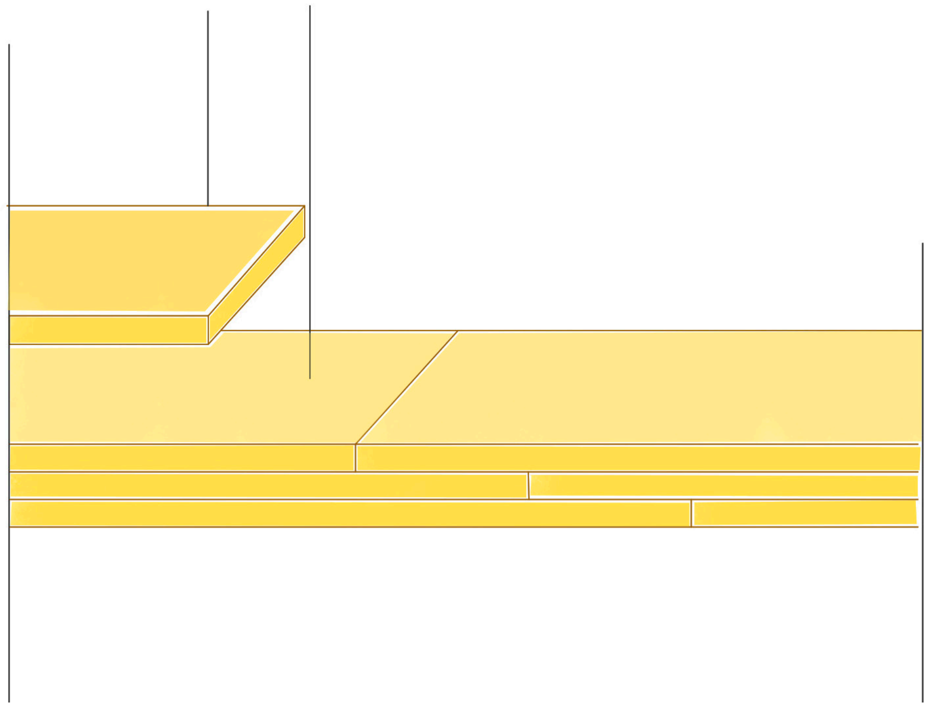


FIGURE 17

FIGURE 17
Staggered arrangement
of fettuccine

3.2.2 FETTUCCINE EXPERIMENTS

We are to make sure fettuccine are glued with proper techniques to prevent uneven surface and to ensure the ease of building with modular units.

Methods
Beams formed using staggered arrangement to ensure that the breaking points are not alligned and thus minimising the number of weak spots.
(Refer to the diagram above)

Layer Experiment
To understand its efficiency and maximum load each can carry, we have tested several types of beam with different orientation to determine which is the best to be implemented in our bridge model.

(i) Horizontal Allignment
(ii) Vertical Allignment
(iii) I-beam Allignment

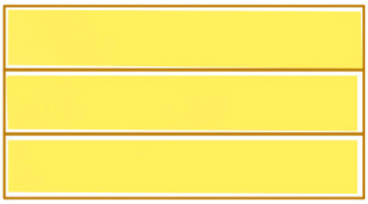


FIGURE 18

FIGURE 18
Horizontal alignment
of fettuccine

3.2.2.1 HORIZONTAL ALIGNMENT

All our fettuccines used are San Remos' and also glued with elephant superglue. Before testing the different fettucine alignments, we have separated the defects out from the good ones as to prevent any problems when testing. We chose to use 150mm span as the constant testing layer length as compared to the clear span of 350mm. Then, we will find out the maximum bearing load of the fettuccines by manipulating the amount of layers. The results were rounded off and are as such:

Length of Fettucine (mm)	Clear Span (mm)	Layers	Max. Bearing Load (Approx.) (g)
			Horizontal
150	350	1	237
150	350	2	376
150	350	3	441
150	350	4	553
150	350	5	729

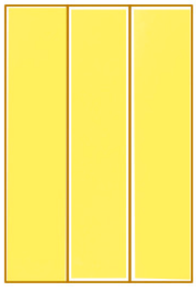


FIGURE 19

FIGURE 19
Vertical alignment of fettuccine

3.2.2.2 VERTICAL ALIGNMENT

As a constant, only the good fettuccines were used again along with the same measurements used in the previous test. We repeated the tests but changed the alignment to vertical and collected the data again. The results are as such:

Length of Fettucine (mm)	Clear Span (mm)	Layers	Max. Bearing Load (Approx.) (g)
			Vertical
150	350	1	242
150	350	2	376
150	350	3	471
150	350	4	580
150	350	5	794

Conclusion:

Based on the testing, it shows that the vertical allignment fettuccine is much stronger compared to the horizontal allignment ones as it bears heavier load.

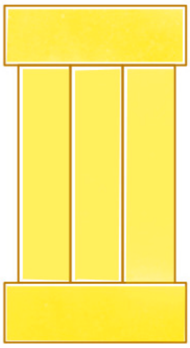


FIGURE 20

FIGURE 20
I-Beam alignment of fettuccine

3.2.2.3 I BEAM ALIGNMENT

Our final test was using I-beams which consist of both vertical and horizontal members. I-beams are made by stacking the webs (vertical layers) and then covered by a layer of flanges (horizontal layers) on both upper and lower side. The results are as such:

Length of Fettucine (mm)	Clear Span (mm)	Layers	Max. Bearing Load (Approx.) (g)
			Horizontal
150	350	1	237
150	350	2	376
150	350	3	441
150	350	4	553
150	350	5	729

Conclusion:
Based on the testing, it shows that the I-beam alignment is strongest compared to the vertical and horizontal allignment. Hence, I-beam allignment is used on ____.

FIGURE 21

FIGURE 22

FIGURE 23

FIGURE 24

FIGURE 21
Elephant glue

FIGURE 22
PVA white glue

FIGURE 23
Hot glue gun

FIGURE 24
Uhu glue

3.3 ADHESIVE ANALYSIS

Different kinds of adhesive are used to ensure the joints are strong and thus strengthen the bridge model.

(i) **Elephant glue**
EFFICIENCY:
- Dries the fastest
- Adhesiveslows into smallest corners and joints

(ii) **UHU glue**
EFFICIENCY:
- Take longer time to dry
- Joints not rigid
- Shifting occurs when load is applied

(iii) **PVA white glue**
EFFICIENCY:
- Water based glue causes fettucine to soften
- Weak joints
- Take longest time to dry

(iv) **Hot glue gun**
EFFICIENCY:
- Bulky finishing
- Long solidify time
- Bad workmanship

FIGURE 25

FIGURE 26

FIGURE 27

FIGURE 28

FIGURE 25
Weighting Machine

FIGURE 26
Bucket

FIGURE 27
Hook

FIGURE 28
Water bottles

3.4 SUPPORT MATERIAL ANALYSIS

Different kinds of support material

(i) Weighting Machine
In determining the weight and mass of an object, weighting machine is used to measure weight of the fettuccine pieces to ensure the final weight of the bridge does not exceed maximum limit of the weight stated in the brief.

(ii) Bucket
Bucket is a vertical cylinder with an open top and a flat bottom. It is used to carry both liquid and solids aiding in the load distribution process.

(iii) Hook
Hook is used to connect or attach the bucket onto the fettuccine bridge to text how much load can it sustain.

(iv) Water bottles
Water bottles are used as loads during test conducting.

4.0 MODEL-MAKING

4.1 PROCESS

FIGURE 29

FIGURE 30

FIGURE 29

Fettuccine of the same length are joined together with several layers.

FIGURE 30

An accurate Autocad drawing of the bridge is printed out as a guide for the bridge construction. Then, the two I-beams are constructed through staggered manner.

FIGURE 31

FIGURE 32

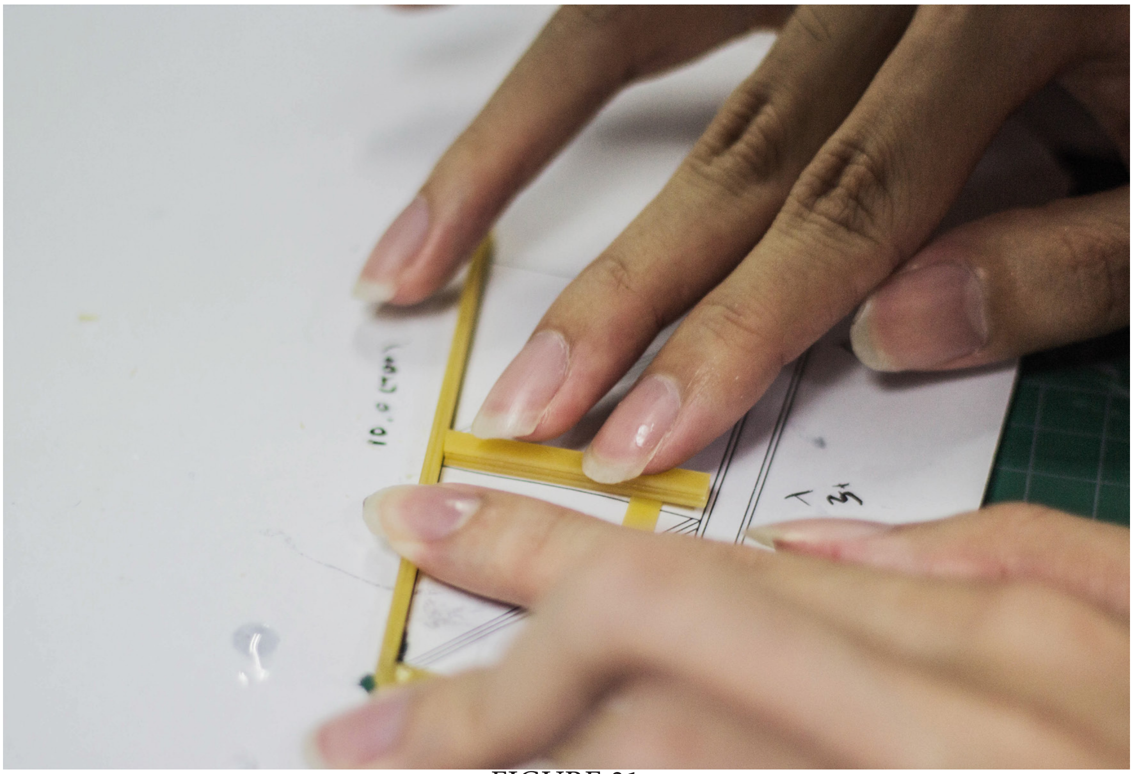


FIGURE 31
Vertical members and the top horizontal members are constructed.

FIGURE 32
Lastly, all components of the fettuccine bridge are carefully and precisely joined together.

5.0 DESIGN DEVELOPMENT & BRIDGE TESTING

5.1 REQUIREMENTS OF FETTUCCINE BRIDGE

a) 350mm clear span bridge.
b) Only fettuccine and glue can be used.
c) Maximum weight of 80g.
d) Bridge will be tested its efficiency.

5.2 FETTUCCINE BRIDGE DESIGN 1

After researching, we used pratt truss as our main truss when designing our bridge. Elephant glue was used as an adhesive for the entire bridge which include joints and to layer up the fettucine.

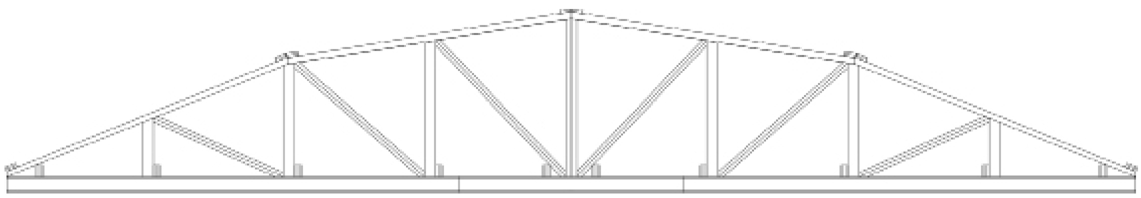


FIGURE 33

FIGURE 33
Elevation view of fettuccine bridge design 1

FIGURE 34
Plan view of fettuccine bridge design 1

FIGURE 35
Roof view of fettuccine bridge design 1

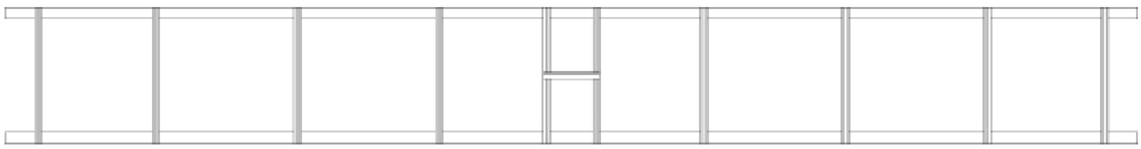


FIGURE 34

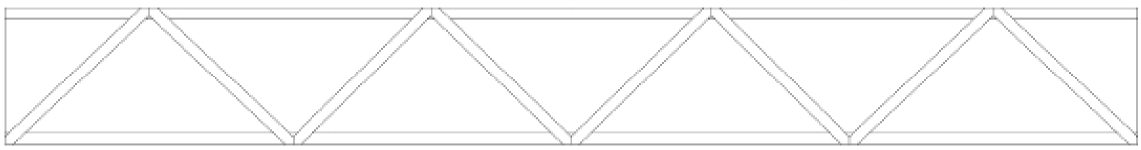
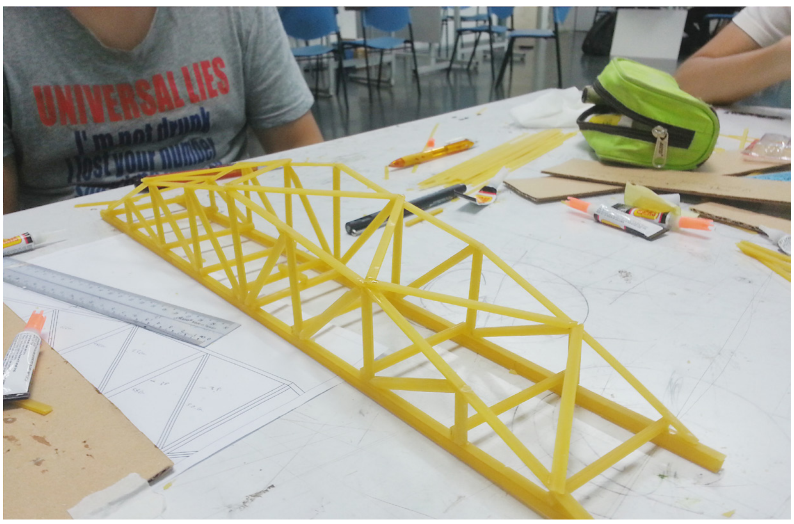


FIGURE 35



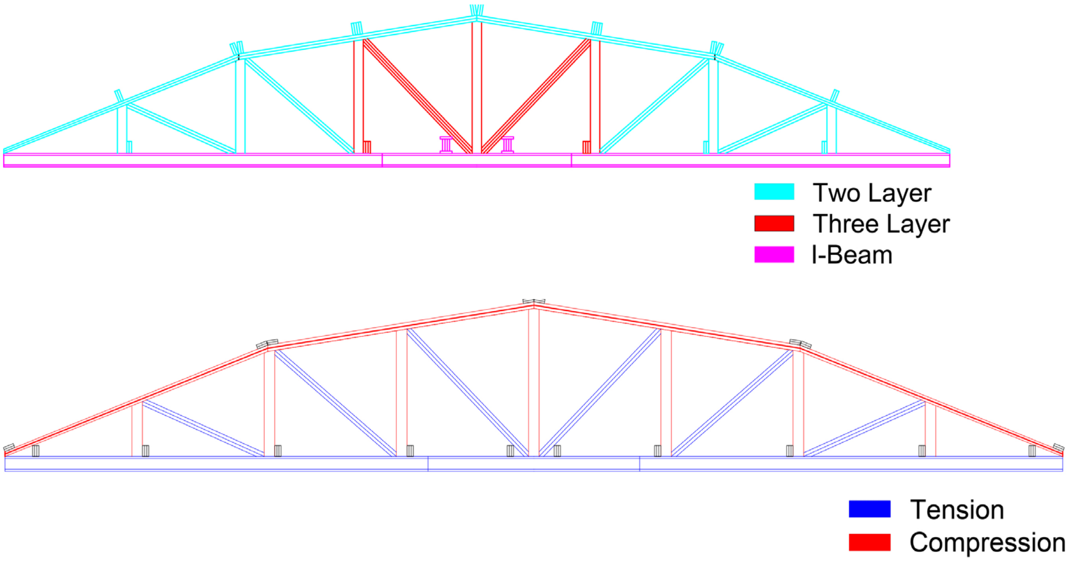


FIGURE 36

TEST 1

Total length	= 500mm	Clear Span	= 350mm
Weight of bridge	= 106g	Load withstood	= 3.5kg
Efficiency	= 115.57		

Design 1 had exceeded the 80g wight limit and did not reach the clear span of 350mm as required but the result exeeded our expectations. The whole bridge was still in great condition after the test but the middle member that withstood the load had broken.

Solution :
1) Enhance the strength of the middle member by adding more layers from 4 layers to 6 layers.

FIGURE 36
Indication of fettuccine layers, tension and compression

FIGURE 37
Indication of solution on plan view

FIGURE 38
Middle member of the fettuccine bridge design 1

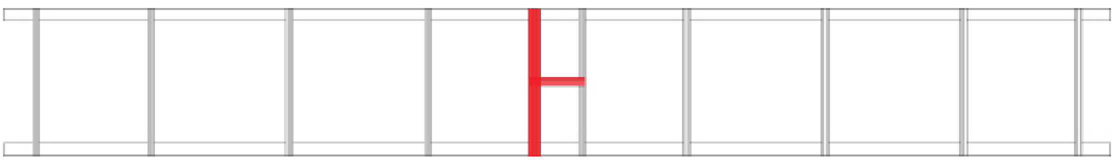


FIGURE 37

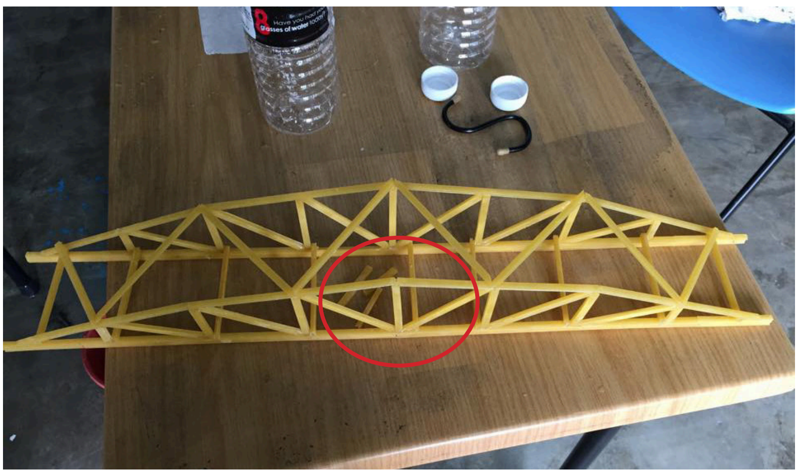


FIGURE 38

TEST 2

We just added 3 more layers to strengthen the part that will hold the load.

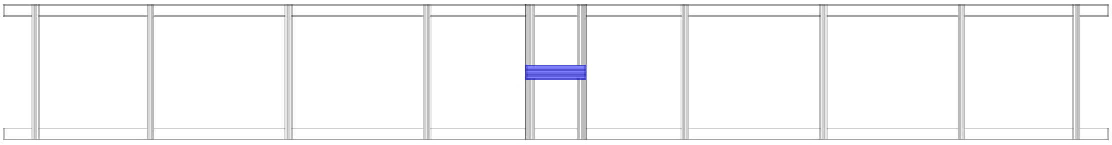


FIGURE 39

FIGURE 39
Indication of added layers on the middle member

FIGURE 40
Fettuccine bridge after test 1

Total length	= 500mm	Clear Span	= 350mm
Weight of bridge	= 107g	Load withstood	= 4.5kg
Efficiency	= 189.25		

The bridge can carry 1kg load more than the previous test. The structure of the bridge still remain in good condition whereas the middle member that withstood the load was broken again.

Solution :
1) Increase the number of member in the middle that holds the load.

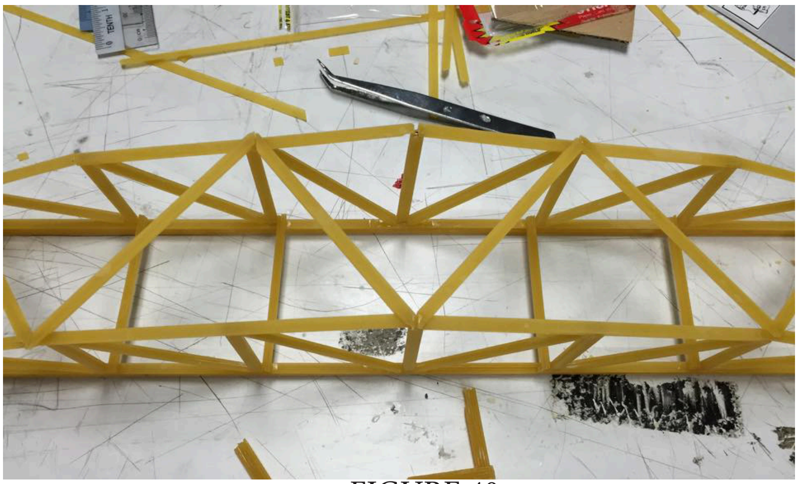


FIGURE 40

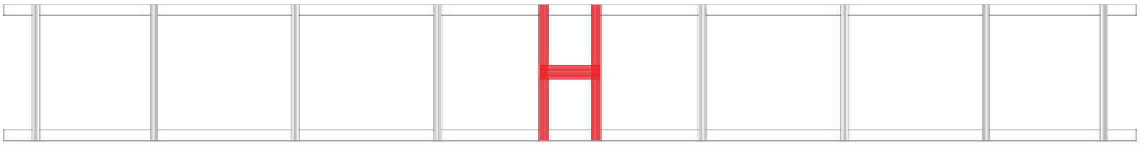


FIGURE 41

TEST 3

We added two middle members which consists of 3 layers of fettuccine.

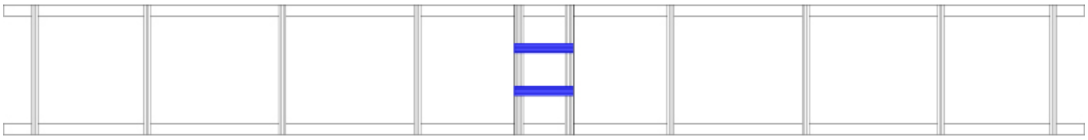


FIGURE 41
Indication of added
 layers on fettuccine
bridge

FIGURE 42
Indication of added
middle members on
fettuccine bridge

FIGURE 42

Total length	= 500mm	Clear Span	= 350mm
Weight of bridge	= 107g	Load Withstood	= 4.6kg
Efficiency	= 197.76		

The bridge can withstand 0.1kg load more than the previous test. The structure of the bridge finally broke apart.

Solution :
1) Decrease the number of layers for each member to achieve the weight requirement.
2) Decrease the length of the bridge to 350mm as it is the requirement for this project.
3) The bracing system of this bridge (Pratt Truss) will be applied to the next design.

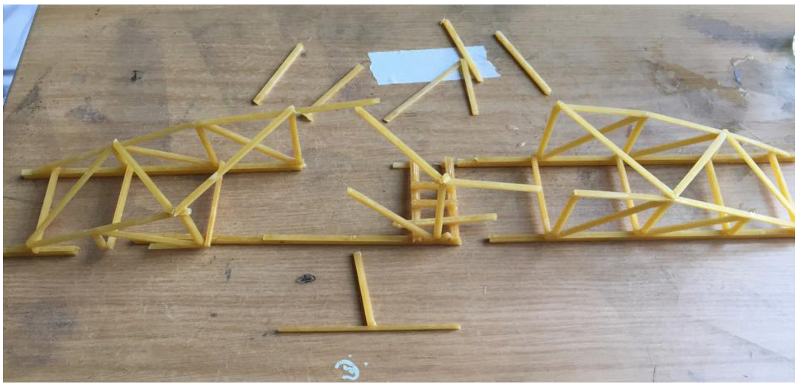


FIGURE 43

FIGURE 43
Fettuccine bridge after test 3

FIGURE 44
Indication of removed members after the test

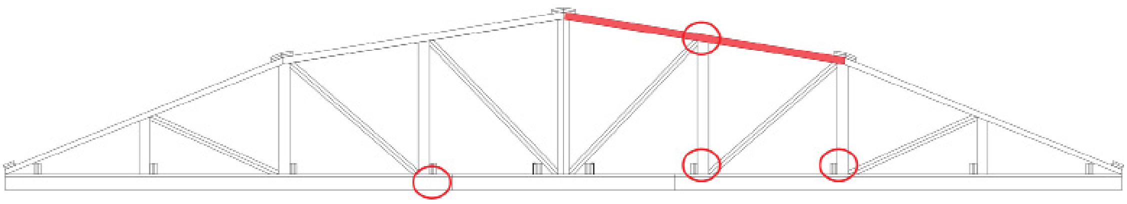


FIGURE 44

5.3 FETTUCCINE BRIDGE DESIGN 2

We applied the Pratt Truss bracing system in our second bridge design. We reduced the number of layer for each member and reduced the length of the bridge in our design to comply with the requirement of this project. We used the elephant glue to stick the member and we let it dry for 10 hours before we run the test.

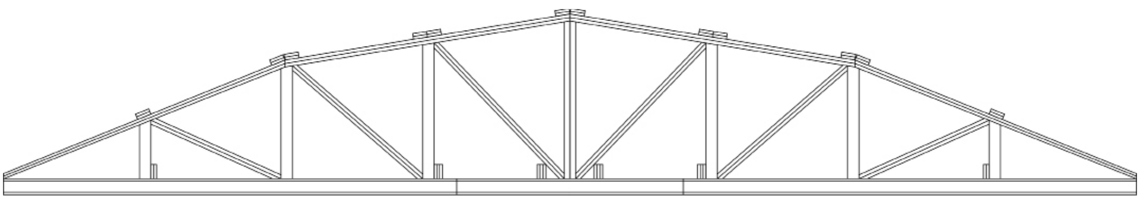


FIGURE 45

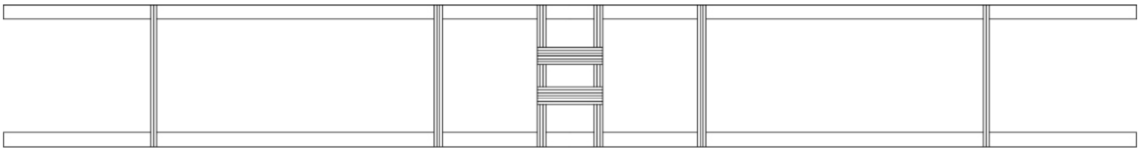


FIGURE 46

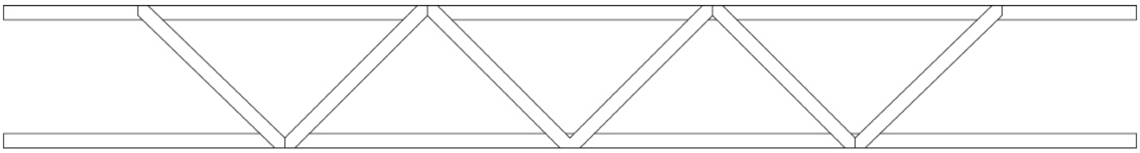


FIGURE 47

FIGURE 45
Elevation view of fettuccine bridge design 2

FIGURE 46
Plan view of fetuccine bridge design 2

FIGURE 47
Roof view of fettuccine bridge design 2

FIGURE 48
Indication of layers of fettuccine bridge design 2

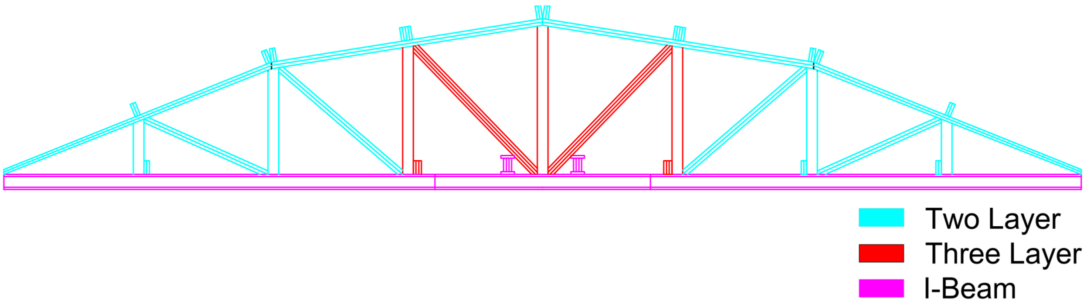


FIGURE 48

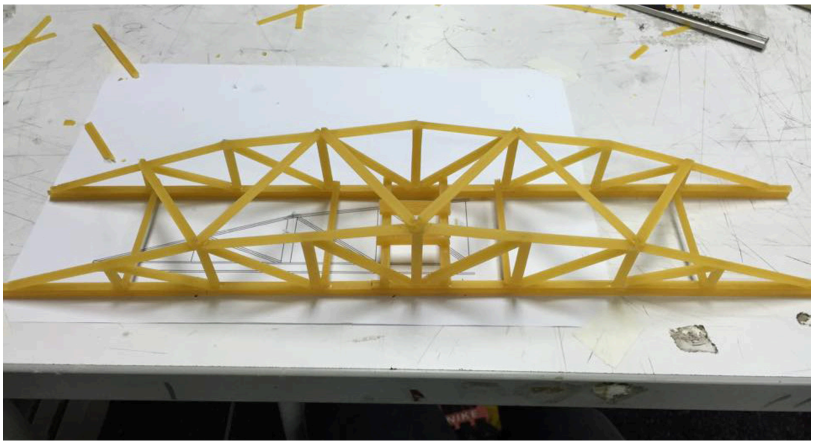


FIGURE 49

Total length	= 400mm	Clear Span	= 350mm
Weight of bridge	= 79g	Load withstood	= 8.5kg
Efficiency	= 926.28		

The bridge can sustain 4kg more than the previous bridge design. The structure of the bridge finally has broken after a 8.5kg load was introduced to it.

Solution :
1) We concluded that this design will be used for our final bridge experiment on the bridge testing day.
2) Change the position of the vertical member to horizontal member which are located on top and the bottom of the bridge.

FIGURE 49
Fettuccine bridge design 2

FIGURE 50
Model Testing of fettuccine bridge design 2

FIGURE 51
Changes made on fettuccine bridge design 2

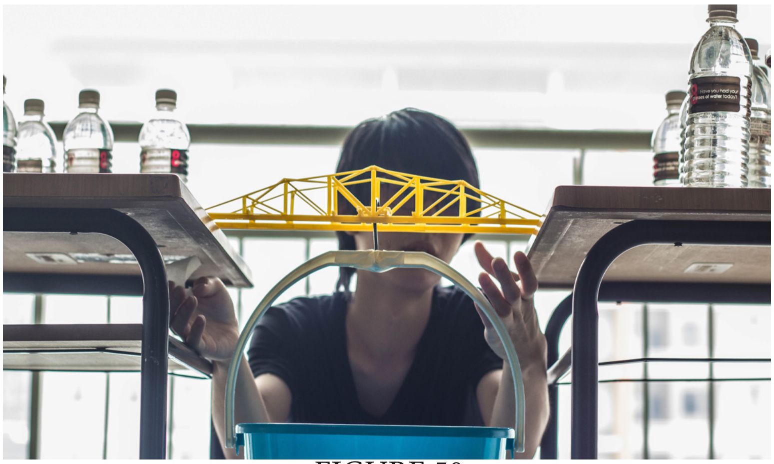


FIGURE 50

FIGURE 51

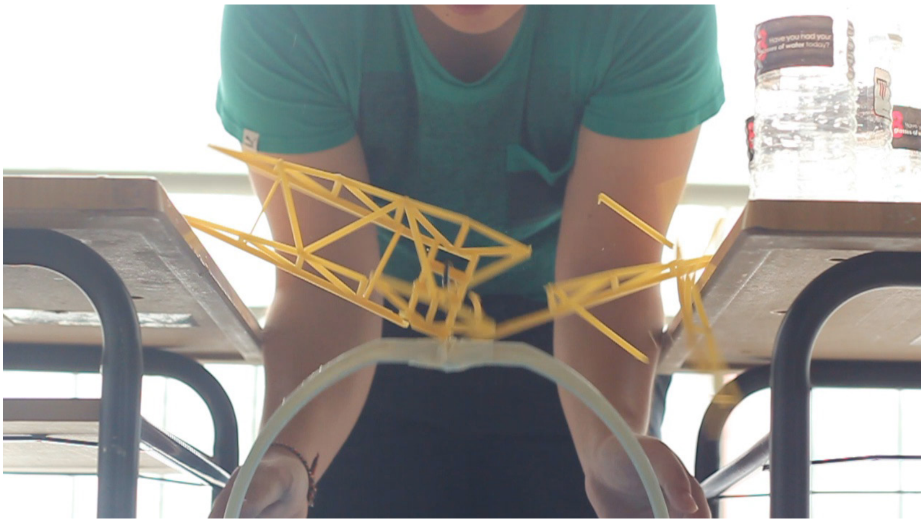


FIGURE 52

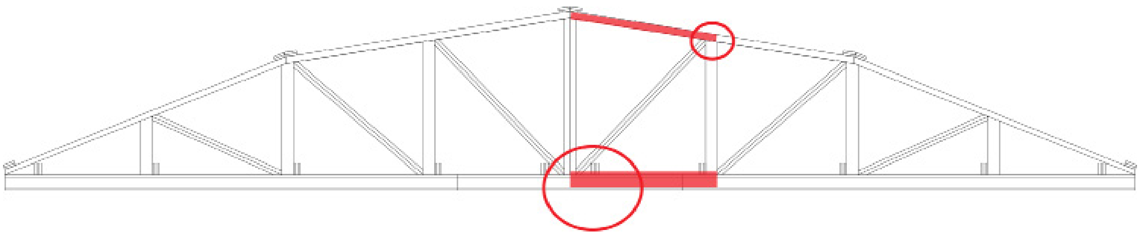


FIGURE 53

FIGURE 52
Breakage of fettuccine design 2 during model-testing

FIGURE 53
Indication of removed members after model-testing

5.4 FETTUCCINE BRIDGE : FINAL

We applied the Pratt Truss bracing system for our final design. The member on top of the bridge was changed from the actual vertical position to the horizontal position. The bottom members were replaced with I-Beam. The time for the bridge to dry was also extended to 15 hours.

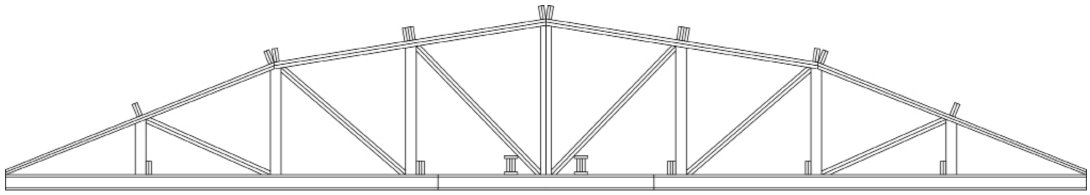


FIGURE 54

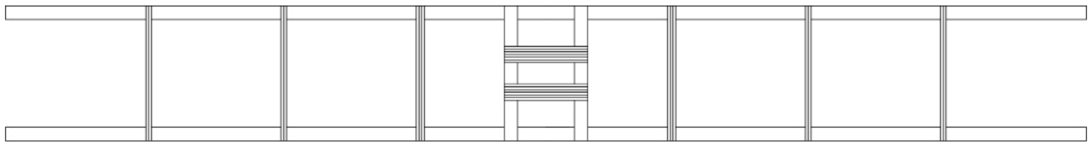


FIGURE 55

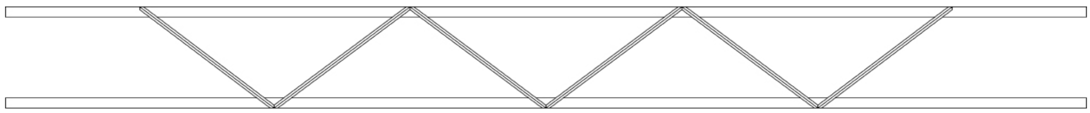


FIGURE 56

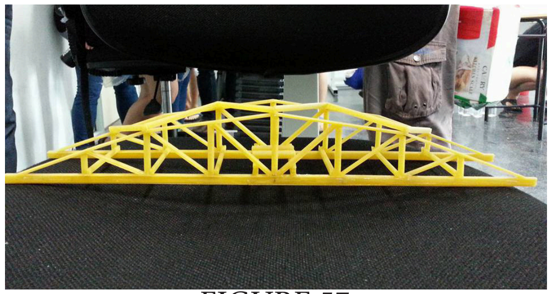


FIGURE 57

FIGURE 58

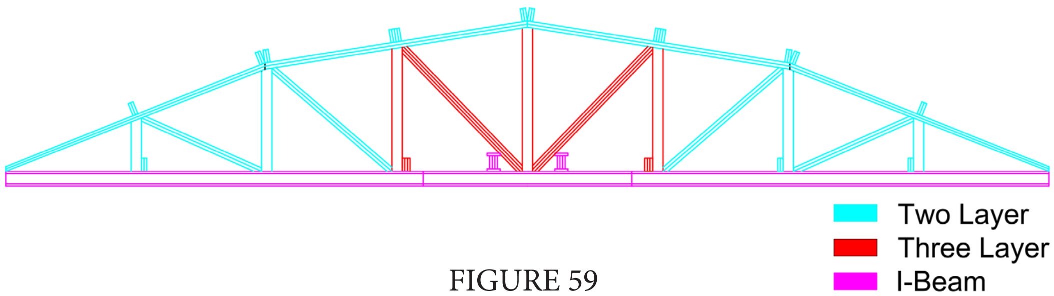


FIGURE 59

FIGURE 54
Elevation view of final fettuccine bridge

FIGURE 55
Plan view of final fettuccine bridge

FIGURE 56
Roof view of final fettuccine bridge

FIGURE 57
Final bridge model

FIGURE 58
Final bridge model

FIGURE 59
Indication of layers on final fettuccine bridge

Total length	= 400mm	Clear Span	= 350mm
Weight of bridge	= 80	Load Withstood	= 8.5kg
Efficiency	= 903.13		

The bridge sustain the same load as the previous bridge but the weight slightly heavier than the second design and the efficiency to decrease.

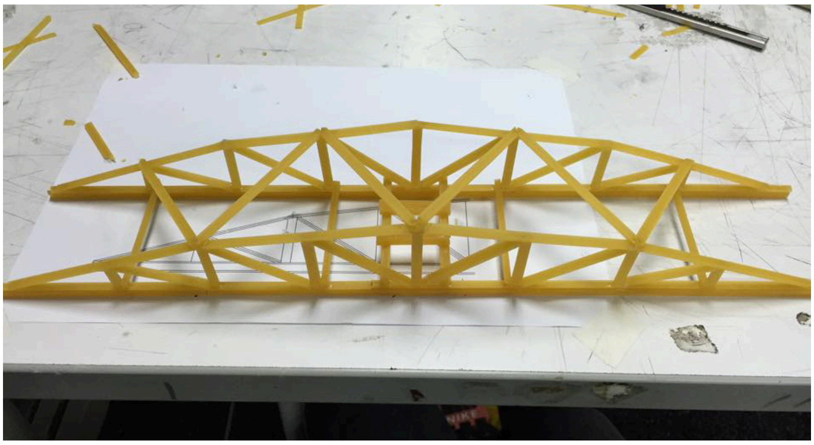


FIGURE 60

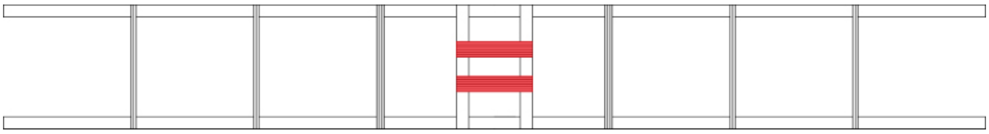


FIGURE 61

FIGURE 60
Final fettuccine bridge model after model-testing

FIGURE 61
Removed members of fettuccine bridge after model-testing

SUMMARY

Good workmanship and good design are the main reason to achieve the high level efficiency. Apparently the efficiency of the final design decreased in a very small amount. What caused the efficiency of the final bridge to decrease was most probably due to the long time spent(15hours) to let the bridge to dry before we put it to the test. We think that, after allowing the bridge to dry for 15 hours, actually made the bridge harden and thus becoming brittle.

6.0 CONCLUSION

We had constructed a total of 3 fettuccine bridges experimented its efficiency in withstanding loads. The precedent study we chose to study on is Long Meadow Bridge.

In our final model testing, we have achieved an efficiency of 903.13 withstanding a total load of 8.5kg and its weight is only 80g. This project has made us understand load distribution in a structure deeper, compared to the previous semester, as we are now able to calculate the type of force applying to identify the force(tension/compression/zero/critical) in structural members in order to achieve high efficient bridge design.

We also realised the importance of proper planning, in terms of work delegation and the time interval between completion of bridge and load testing. It is due to the efficiency of completing the bridge on time and giving an adequate time for the adhesives to dry out and maintain its strength until load testing.

In conclusion, it has been a great experience working on this project. Using household goods to construct a bridge and gaining so much knowledge after that have amazed us how strong a structure can be if its properly designed and constructed. As an architecture students, we will be the leader in the construction industry in the furure, we need to think critically and pay attention to details so that a structure can function efficiently without failure for the safety and well being of the people.

7.0 APPENDIX

As for our individual part, each of us were distributed to the following exercise:

CASE 1 (Pua Zhi Qin)
CASE 2 (Ling Siaw Zu)
CASE 3 (Tang Kar Jun)
CASE 4 (Carmen Chee Cha Yi)
CASE 5 (Adrian Seow Chen Wah)
CASE 6 (Ho Tze Hooi)

The analysis and calculation of trusses are attached after this page.

8.0 REFERENCES

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O'Connor, C., & Shaw, P. (2000). Bridge loads. New York: E & FN Spon.