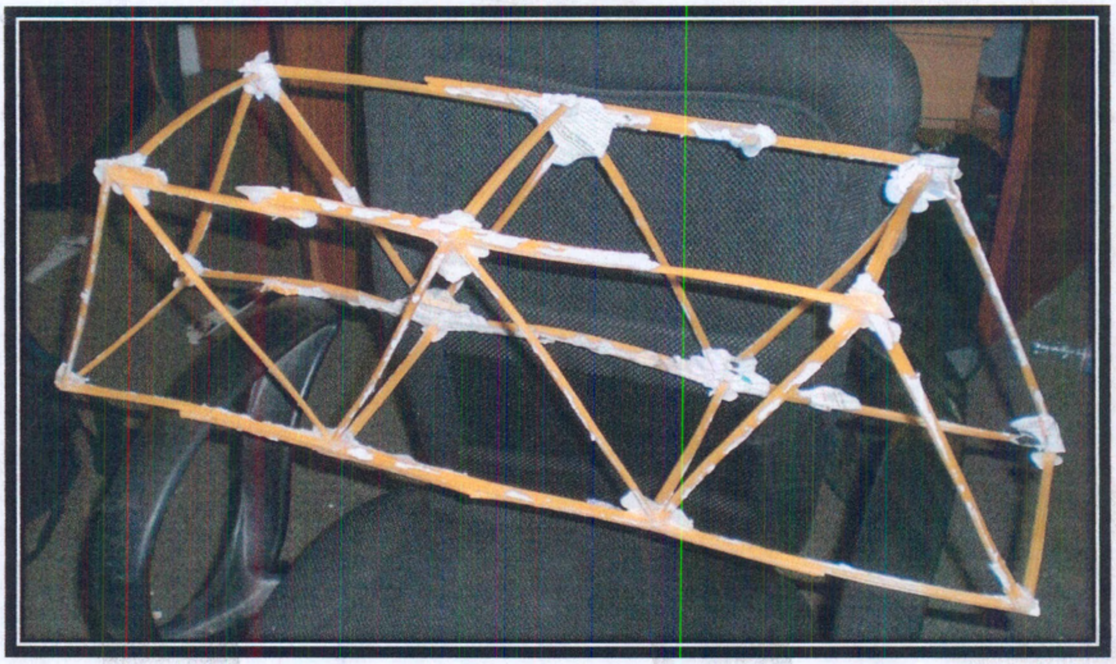
The Spaghetti Bridge Project



Date of Competition:

November 25, 2008

Team Members:

85/100
some great stuff, but weaknesses too.

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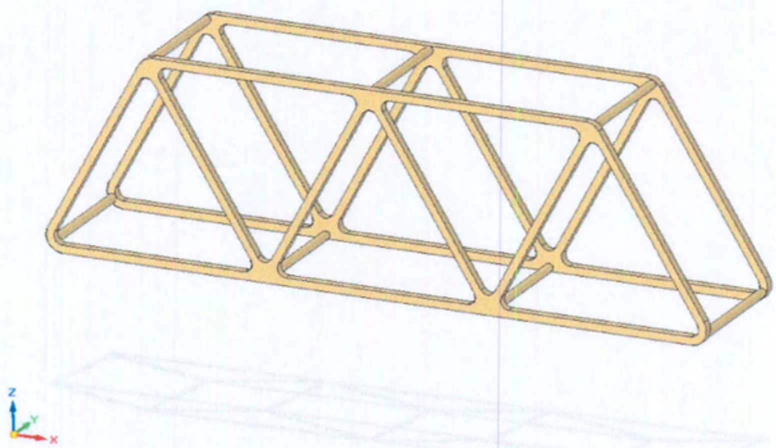
Goal of "Spaghetti Bridge" Project

The goal of this project is to create a bridge that spans 25 inches wide, solely using spaghetti and white glue. The bridge must be sturdy, and at a minimum, be able to hold the weight of the bucket that will be tied to it. Then, weights will be put into the bucket. The ultimate goal of the bridge is to have the highest weight held to bridge weight ratio.

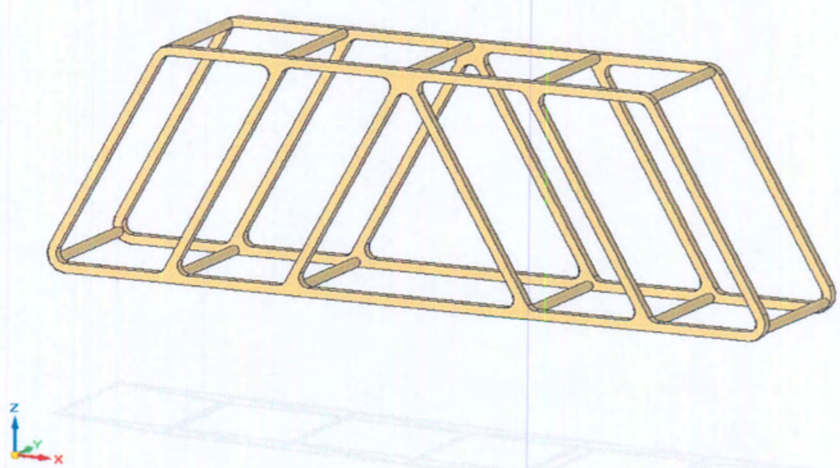
Drawing of Preliminary Designs

Length of Each Spaghetti Piece is 10 inches

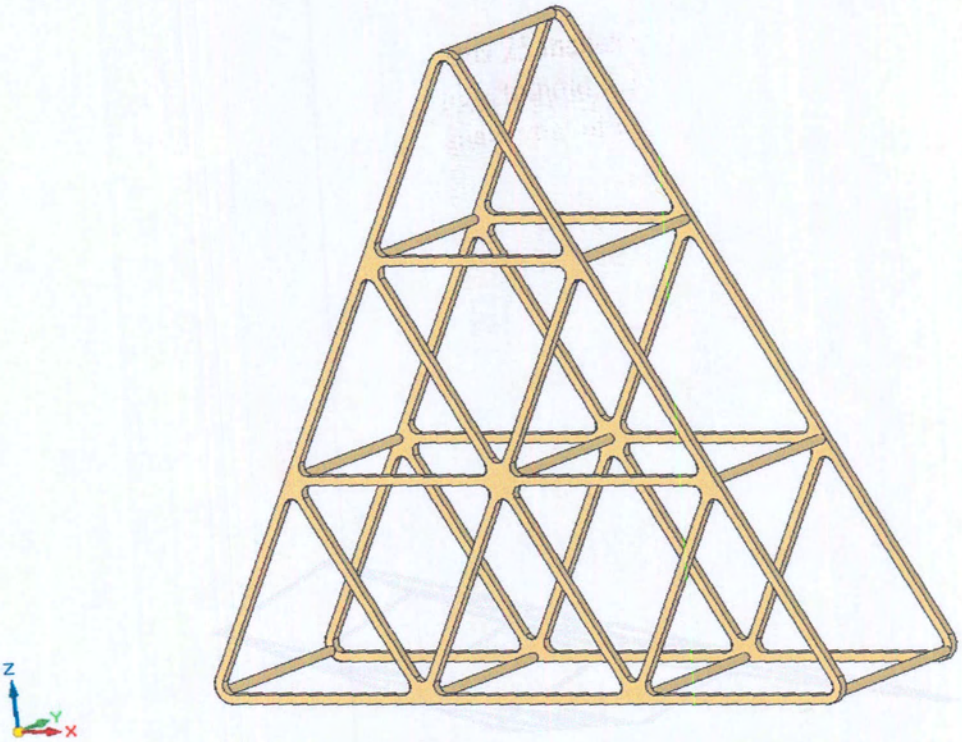
Design 1



Design 2



Design 3



Design 4

nice pics!

Critique of Preliminary Design Concepts

(Introductions of Designs)

Test-Run Data

Solid edge material used for stress test: Polyethylene, low density

good!

Similar physical properties to spaghetti:

	Elastic Modulus (ksi)	Yield Stress (ksi)
Polyethylene, low density	21.000	1.400
Spaghetti	27.500	1.334

where did you get this info?

Design #1

1. Introduction

This design seemed to be sturdy and practical. The beams in the center distribute the weight to the sides of the bridge, where there is more support. Also, unlike the triangle design, this is able to distribute the weight without having unnecessary spaghetti weight at the top.

2. Part Properties

Part Name	Design 1.par
Mass	0.0236 lbm
Volume	24.053 in^3
Weight	0.760 lbf

3. Material Properties

Material Name	ABS Plastic, medium impact
Mass Density	0.037 lbm/in^3
Young's Modulus	330.000 ksi
Poisson's Ratio	0.400
Thermal Expansion Coefficient	0.0000 /F
Thermal Conductivity	1.156 BTU/hr-ft-F
Yield Strength	6.300 ksi
Ultimate Strength	0.000 ksi

4. Load and Constraint Information

Load Set

Load Set Name	Load 1
Load Type	Pressure
Number of Load Elements	2
Load value	0.000 ksi

Constraints

Number of Constrained Faces	2

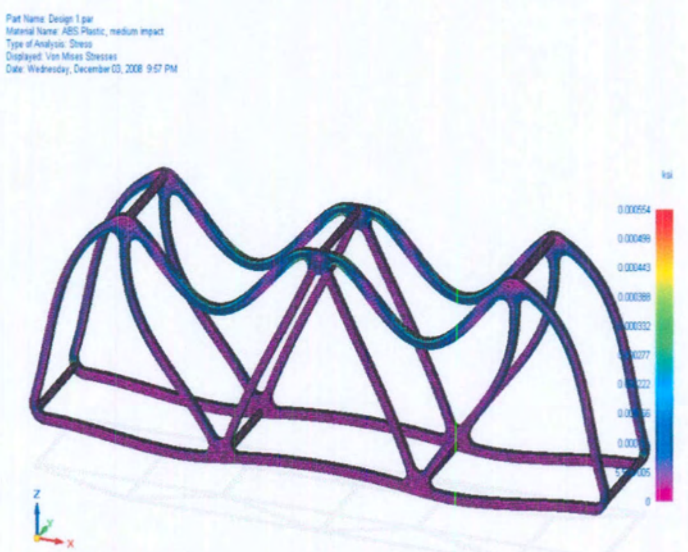
5. Study Properties

Mesh Type	Tetrahedral Mesh
Number of elements	63,048
Number of nodes	132,464
Solver Type	Nastran

6. Stress Results

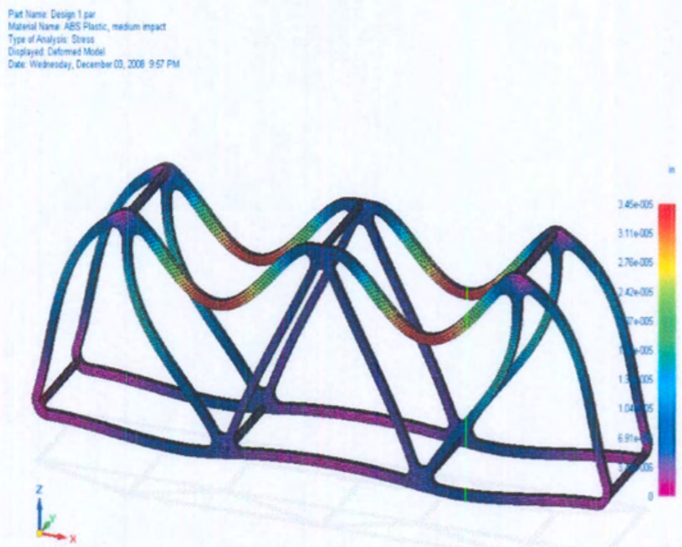
explain how obtained - where is load?

Type	Extent	Value	X	Y	Z
Von Mises Stress	Minimum	0.000e+000 ksi	14.433 in	0.991 in	0.128 in
	Maximum	5.538e-004 ksi	0.790 in	5.583 in	8.464 in



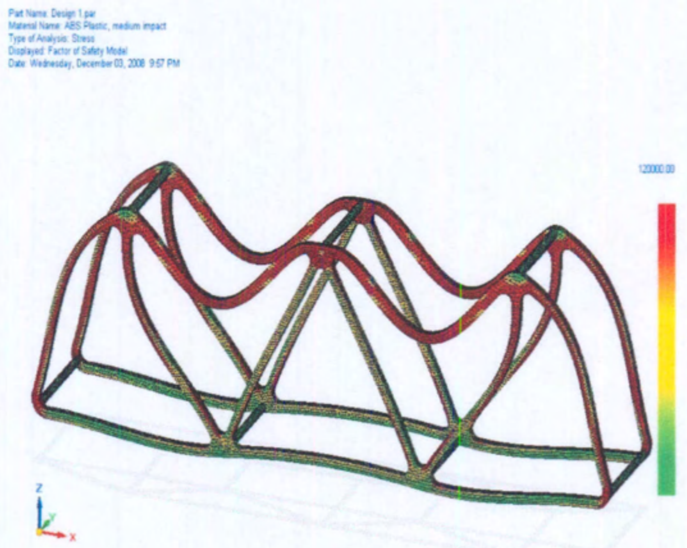
7. Displacement Results

Type	Extent	Value	X	Y	Z
Resultant Displacement	Minimum	0.000e+000 in	14.394 in	0.991 in	0.350 in
	Maximum	3.454e-005 in	-5.460 in	5.350 in	8.602 in



8. Factor of Safety

Factor of Safety Value	11376.795



Design #2

1. Introduction

The goal of this design is to distribute the weight to the side. However, the supports in the center are in parallelogram shape, causing the beams to go in one direction, ultimately causing our bridge to cave in the center.

2. Part Properties

Part Name	Design 2.par
Mass	0.0236 lbm
Volume	24.053 in^3
Weight	0.760 lbf

3. Material Properties

Material Name	Polyethylene, low density
Mass Density	0.032 lbm/in^3
Young's Modulus	21.000 ksi
Poisson's Ratio	0.350
Thermal Expansion Coefficient	0.0001 /F
Thermal Conductivity	2.253 BTU/hr-ft-F
Yield Strength	1.400 ksi
Ultimate Strength	0.000 ksi

4. Load and Constraint Information

Load Set

Load Set Name	Load 1
Load Type	Pressure
Number of Load Elements	2
Load value	0.000 ksi

Constraints

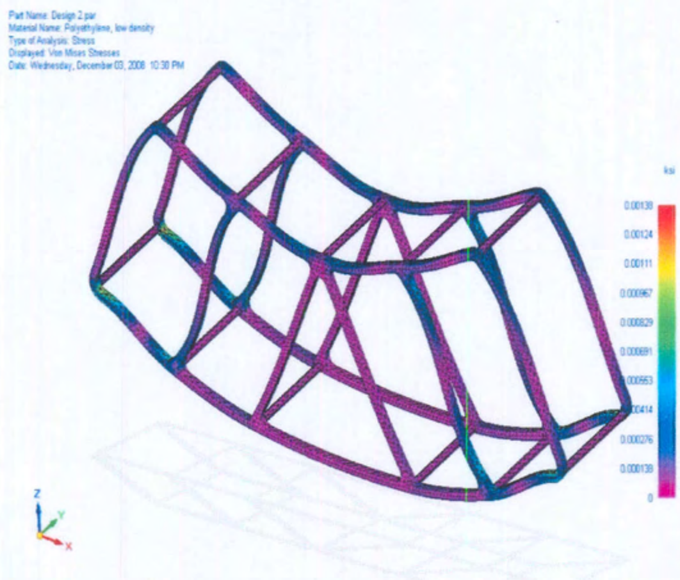
Number of Constrained Faces	2

5. Study Properties

Mesh Type	Tetrahedral Mesh
Number of elements	23,631
Number of nodes	54,549
Solver Type	Nastran

6. Stress Results

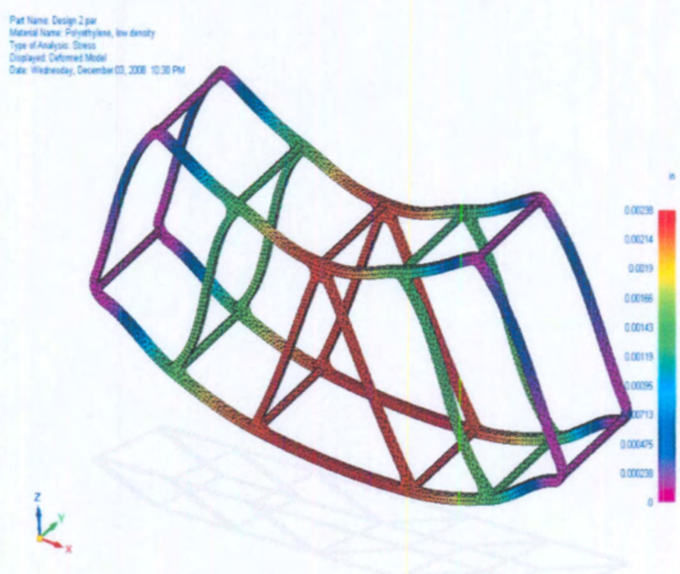
Type	Extent	Value	X	Y	Z
Von Mises Stress	Minimum	0.000e+000 ksi	14.718 in	2.433 in	0.293 in
	Maximum	1.382e-005 ksi	14.586 in	0.350 in	0.030 in



Great stuff but you need to explain what you did

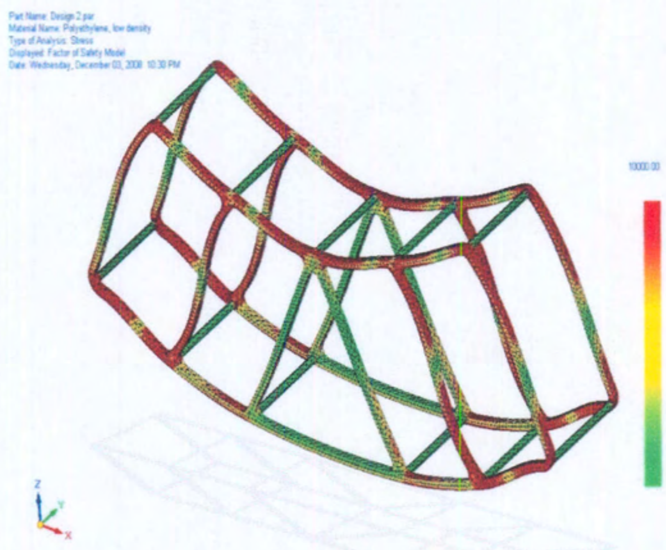
7. Displacement Results

Type	Extent	Value	X	Y	Z
Resultant Displacement	Minimum	0.000e+000 in	14.545 in	2.433 in	0.088 in
	Maximum	2.376e-003 in	0.000 in	0.000 in	0.000 in



8. Factor of Safety

Factor of Safety Value	1013.341



Design #3

1. Introduction

The goal of this equilateral triangle is to distribute the weight to the sides where there is support. However, due to the fact that the bridge had to be at least 25 inches wide, this structure would be very large, and we thought. inefficient. There seem to be other ways to distribute the weight to the sides without having the extra triangular section at the top.

2. Part Properties

Part Name	Design 3.par
Mass	0.0387 lbm
Volume	39.447 in^3
Weight	1.246 lbf

3. Material Properties

Material Name	Polyethylene, low density
Mass Density	0.032 lbm/in^3
Young's Modulus	21.000 ksi
Poisson's Ratio	0.350
Thermal Expansion Coefficient	0.0001 /F
Thermal Conductivity	2.253 BTU/hr-ft-F
Yield Strength	1.400 ksi
Ultimate Strength	0.000 ksi

4. Load and Constraint Information

Load Set

Load Set Name	Load 1
Load Type	Pressure
Number of Load Elements	2
Load value	0.000 ksi

Constraints

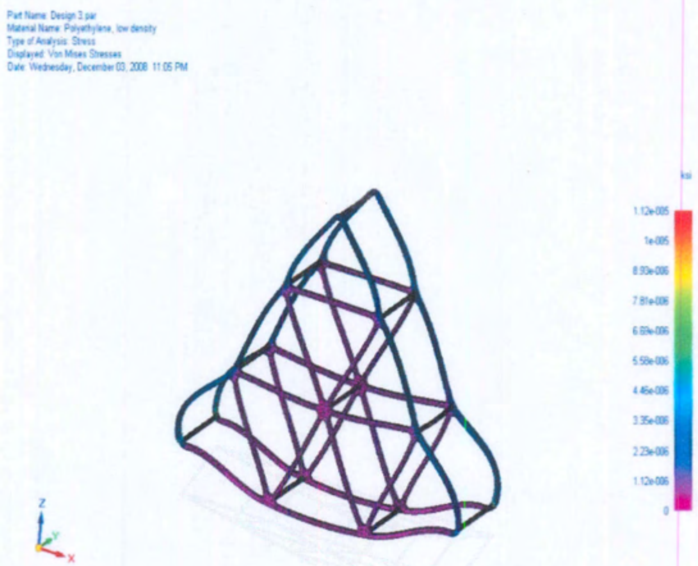
Number of Constrained Faces	2

5. Study Properties

Mesh Type	Tetrahedral Mesh
Number of elements	20,345
Number of nodes	49,236
Solver Type	Nastran

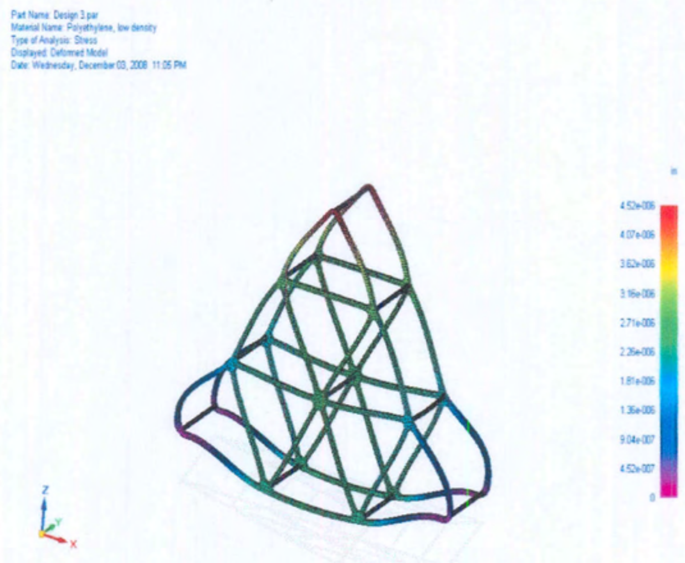
6. Stress Results

Type	Extent	Value	X	Y	Z
Von Mises Stress	Minimum	0.000e+000 ksi	-14.545 in	2.310 in	0.437 in
	Maximum	1.116e-005 ksi	-14.780 in	7.350 in	0.403 in



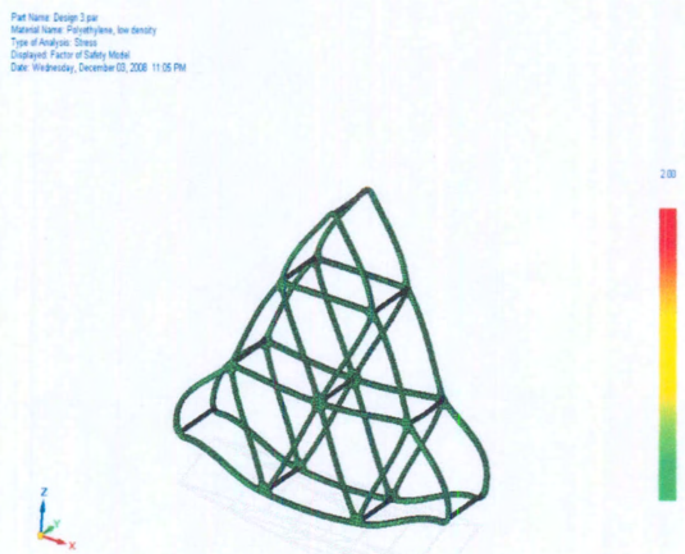
7. Displacement Results

Type	Extent	Value	X	Y	Z
Resultant Displacement	Minimum	0.000e+000 in	-14.545 in	2.310 in	0.437 in
	Maximum	4.519e-006 in	0.175 in	3.990 in	25.456 in



8. Factor of Safety

Factor of Safety Value	12548.330



Design #4

1. Introduction

Since our spaghetti was relatively flexible, this seemed as though it might be a reasonable design, since it would bend with the weight that is applied to it. However, we realized that the bridge would probably wind up collapsing at the point where the weight was applied, since it would not be distributed anywhere.

2. Part Properties

Part Name	Design 4.par
Mass	0.0709 lbm
Volume	72.159 in^3
Weight	2.280 lbf

3. Material Properties

Material Name	Polyethylene, low density
Mass Density	0.032 lbm/in^3
Young's Modulus	21.000 ksi
Poisson's Ratio	0.350
Thermal Expansion Coefficient	0.0001 /F
Thermal Conductivity	2.253 BTU/hr-ft-F
Yield Strength	1.400 ksi
Ultimate Strength	0.000 ksi

4. Load and Constraint Information

Load Set

Load Set Name	Load 1
Load Type	Pressure
Number of Load Elements	13
Load value	0.000 ksi

Constraints

Number of Constrained Faces	2

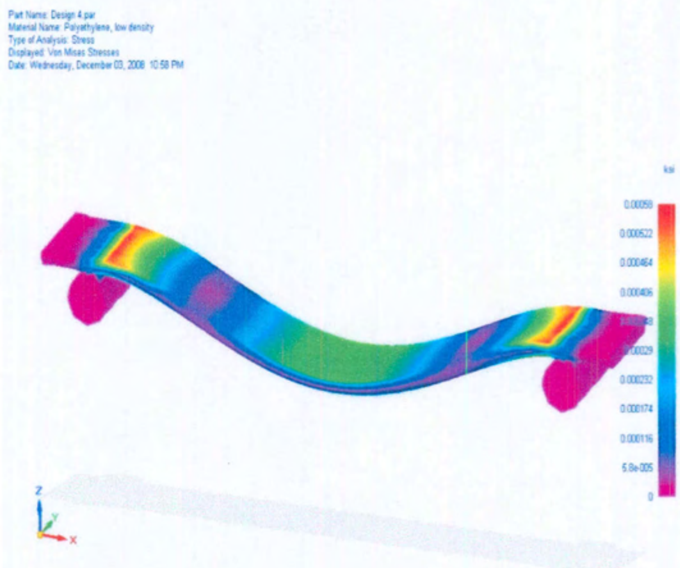
5. Study Properties

Mesh Type	Tetrahedral Mesh
Number of elements	11,993
Number of nodes	21,357
Solver Type	Nastran

o/c

6. Stress Results

Type	Extent	Value	X	Y	Z
Von Mises Stress	Minimum	0.000e+000 ksi	-13.375 in	2.249 in	0.374 in
	Maximum	5.197e-004 ksi	-11.130 in	1.236 in	0.747 in

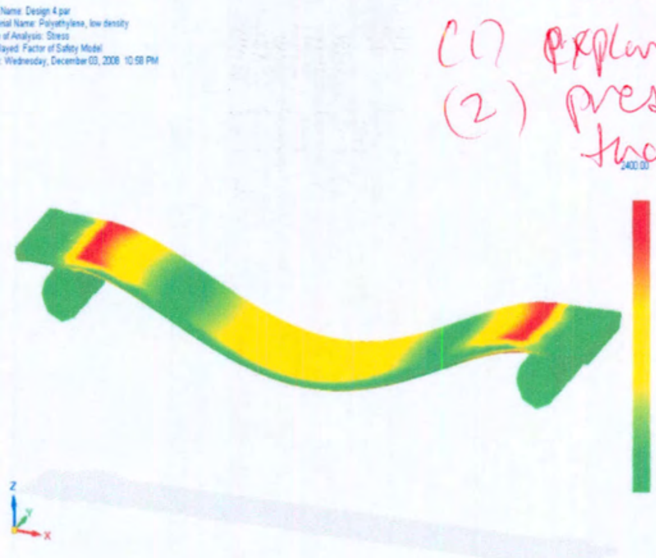


7. Displacement Results

Type	Extent	Value	X	Y	Z
Resultant Displacement	Minimum	0.000e+000 in	13.207 in	2.298 in	-0.818 in
	Maximum	1.963e-003 in	0.000 in	2.141 in	1.068 in

8. Factor of Safety

Factor of Safety Value	2415.056



Great analysis, but (1) explain what you did (2) present results in a table that clearly shows which satisfies objective the best. (3) why didn't you try to improve any of the designs by adding more material where it failed first?

Choosing of Final Design

After analyzing the data, we came to the conclusion that design number 1 was the best to use for our bridge. At first glance, we took notice that design number 3 had the highest safety factor of 12549.330, and right behind it was design number 1, with 11376.795. However, analyzing the ratio between design 3 to design 1, we saw that design 3 weighed 1.64 times the weight of design 1 (1.246 lbf / .76 lbf). Even though design 3 had a better safety factor, by a ratio of 1.103, we decided that since this contest was judged on weight held to weight of bridge, this would not yield the best results. Furthermore, when looking at the yield stresses produced by solid edge, design number 1 had the highest yield stress, though design number 4 was close behind. However, due to design number 4's low safety factor and high weight, we decided that it would not be a good candidate.

Therefore, it was only intuitive to pick design number 1 as the final design for our bridge for this competition.

strength/weight is the only thing that matters.

Bridge Construction

The only materials we were allowed to use in our construction were spaghetti and white glue. At first, we created of bundles of 10 pieces of spaghetti, with and without glue, and weighed them. The average glued bundle to not glued bundle ration was approximately 1.6, so we realized that this would add significant weight to our bridge. Therefore, we opted to find other ways to stick the spaghetti together, so that we could lower the mass to weight held ratio of our bridge.

We thought that microwaving the spaghetti might cause it to melt together, or boiling and letting the spaghetti dry in bundles. However, none of these methods worked, as microwaving the spaghetti made it more brittle and it did not stick together, and boiling and letting the spaghetti dry made it too soft and flexible. We therefore resorted to using white glue for our whole project.

We began by creating bundles of 10 pieces of spaghetti, and applying glue all over them, so they became sturdy rods. We reapplied glue multiple times to maximize the strength of these rods. We created approximately 60 of these rods, and afterwards, picked the ones that were most symmetrical to use in our bridge.

We laid out the rods of spaghetti into their respective shapes, and made 3 frames for our bridge. To connect the joints of the bridge, we used large amounts of glue, and let them dry over night. For about 4 days, we continually reapplied glue to these spots, in order to increase the size and strengths of the joints.

Then, after these were dried and sturdy, we looked and decided which 2 of the 3 frames had turned out the best. Then, we took some extra rods of spaghetti and reapplied them to sections of the bridge that could use reinforcement. After these had dried as well, we then took the two frames and stood them up, approximately 5 inches apart. We connected these frames with rods that were only 5 inches apart. Again, we applied much glue to the joints, and let it dry, and then continuously reapplied the glue to strengthen the joints for three more days.

why 5"?

Results

The bridge ended up weighing 345 grams. This was roughly the weight that we predicted that design number 1 would be, and though not the lightest in the competition, it was certainly not the heaviest. A noted difference between our bridge and other bridges of the same weight was that our bridge was much larger, in height and width. This bridge design is stronger than bridges smaller in height, because smaller bridges are less able to distribute the weight down the sides, instead of down the middle. Unfortunately there was a glaring flaw in our bridge. When weight was applied, the bridge began to collapse sideways, since it was not constructed using exact perpendicular angles. This stopped the bridge from being able to distribute the weight down the sides, and therefore compromised its ability to hold more weight, and left the weight supported on the one side of our spaghetti beams.

The original shape of the bridge put the weight on the ends but once collapsed the weight was all on the sides which led to the bridge breaking. Due to this collapse, the bridge only held 5.6 pounds of sand and bucket. While this weight was less than expected it still led to a ratio of 8.36. After all the groups tested their respective bridges, our rank turned out to be 11. If the bridge had stayed upright, this ratio and rank would have been much higher. In hindsight, an addition to be made to the bridge that would have more than made up for its extra weight would have been two more beams, placed in the middle of the bridge stretching from the lower corner to the opposite top corner. This would not have helped carry any load, but it would have prevented the bridge from failing laterally.

increases strength but does it increase strength/weight?

While a shorter bridge would have been less likely to fail sideways, we still believe building a tall bridge was the best course of action. The method of gluing a bundle of strands of spaghetti into a beam worked well. Ultimately, the only thing that would have been needed to much improve our performance would have been the addition of two beams.

What We Would Do Differently

There are four major things that we would have done differently:

1. More secure joints - this would have helped the sturdiness of our bridge. This happened to be the failing point of our bridge in the competition.
2. Strengthen Rods – we made many rods that were constructed by using 10 pieces of spaghetti glued together. However, some of these rods did not seem to be as strong as others, and it was another failing point.
3. More symmetrical rods – each of the rods that we created using 10 pieces of spaghetti were slightly differently shaped. Their cross-sections were not perfectly circular, which is what we wanted. This made our bridge not symmetric, which caused some trouble.
4. Using wax paper – when we created our bridge and the glue was drying, we placed the spaghetti on newspaper, rather than wax paper. After the glue had dried, we struggled greatly to rip off the newspaper, and it actually caused our bridge to snap in some places, which we had to try to fix, creating weak points.
5. Insert two beams – since our bridge failed laterally, the inserting of two beams to keep the bridge's stability would have been very helpful in keeping our bridge upright.

Kinda thin here

Communication

Our group met on three different occasions to design our bridge, and three times to build it.

Meeting 1: November 4

This meeting took place outside of Leavey Library. It was the first time our group assembled, and we began to do the preliminary sketches for our bridges. We concluded this meeting with four possible designs.

Meeting 2: November 9

At this meeting in Brad's room, we created three dimensional versions of our bridge designs on solid edge. We ran the stress tests, and figured out which bridge we would like to use.

Meeting 3: November 12

We got together and went to Superior, the local grocery store, to purchase the mass quantities of pasta that we needed for our bridge (we had small amounts of pasta that we used earlier for testing).

Meeting 4: November 19

This was the first meeting where we began the construction of our bridge. We created the many bundles of spaghetti (rods) for our bridge, and let them dry.

Meeting 5: November 22

We began the construction of the three frames (two of which we used) at this meeting. We laid them out on newspaper, and we poured lots of glue to create strong joints.

Meeting 6: November 24

This was our final meeting, where we connected the two frames that turned out the best. This was more difficult, since we had to make sure that our frames remained a certain distance apart while drying, and that they stayed parallel to each other.