Final Design Report

| EK301 A3 | Fall 2021 |

Professor Holt

Brought to you by *The Foreigners*

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Introduction

The purpose of this experiment is to design a truss capable of handling a heavy load with the lowest cost to build it. We decided to approach our final design by focusing on the price. We attempted many different structures using the Matlab program created from the previous report; however, none met our minimum design requirements. The requirements for this final truss design are as follows:

Summary of distance and cost specifications

Joint-to-joint span L_{jj}	$6.0\ in. \leq L_{jj} \leq 15\ in.$
Truss span	$29\ in.$
Load to pin support span	$15\ in.$
Total virtual cost	$< \$285$

In the end, we decided to use our first design from the preliminary design report as our final design. It met all of the requirements above, with a theoretical max load of 33.5 oz ± 8.9 oz. We strived to minimize uncertainty to maximize the predicted strength of the truss by using the data collected from the buckling lab experiment. This report will further discuss optimizations made for our final design and explain our motivation and approach.

Procedure

We used Matlab to make our calculations and analyze the truss, testing numerous designs that will help us reach the ultimate goal. In the end, we decided to maintain our first truss design from the previous report because it provided solid results and met the minimum requirements. We concluded that our strategy is reliable and has great potential to perform well in a real-life environment. Hence, after careful consideration, we did not make any significant changes to our final design.

Analysis

Based on the preliminary design report, we discovered that there are three zero force members, meaning that those members do not affect carrying the load. Removing these members would make the design cheaper but could also compromise the integrity of the structural support. If we decided to take away those zero force members, there would be extra members on one side compared to the other. This additional member occurs because a longer side needs extra support to make the truss stable with our load inserted at the center.

Results

Final Design

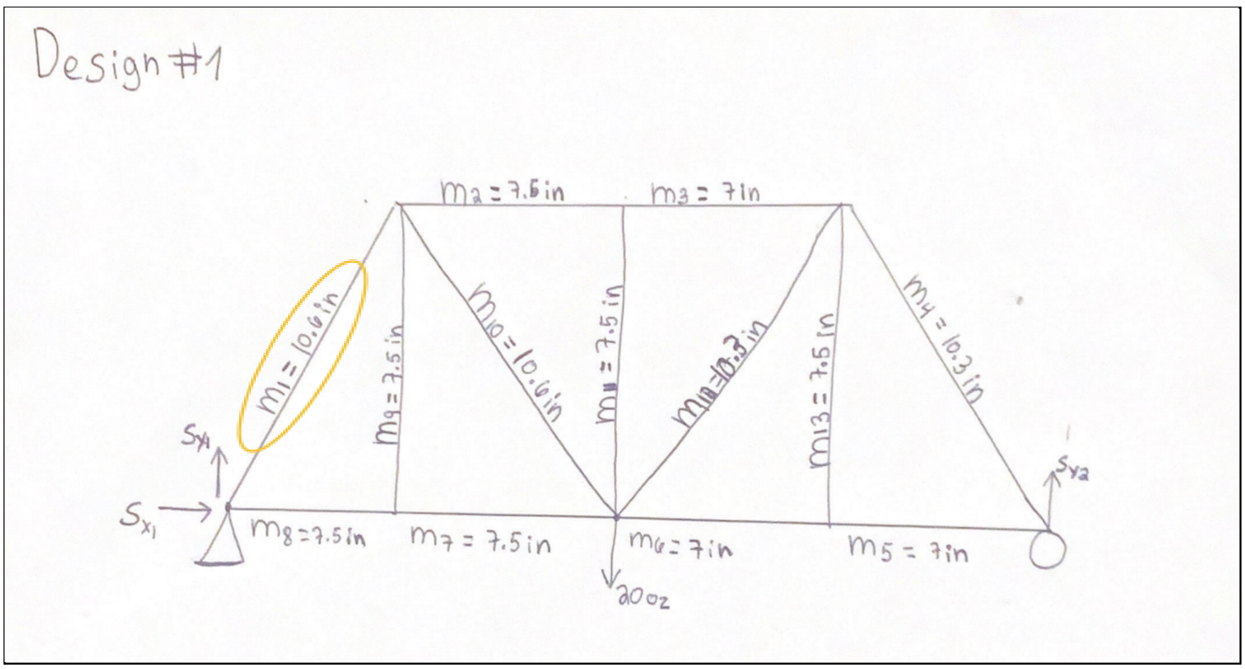

Figure 1. TrussFinalDesign. Member to buckle first highlighted in yellow

Figure 2. TrussFinal Built. Member to buckle first highlighted in yellow

Data Collection

m	Length (in)	Force	(C) or (T)	Buckling Strength (± 8.9 oz)	Max Load (oz)
m1	10.6	13.7	(C)	22.8	33.5
m2	7.5	19.3	(C)	45.7	47.3
m3	7	19.3	(C)	52.5	54.3
m4	10.3	14.2	(C)	24.4	34.5
m5	7	9.66	(T)	52.4	109
m6	7	9.66	(T)	52.4	109
m7	7.5	9.66	(T)	45.7	94.6
m8	7.5	9.66	(T)	45.7	94.6
m9	7.5	0	N/A	45.7	Inf
m10	10.6	13.7	(T)	22.8	33.5
m11	7.5	0	N/A	45.7	Inf
m12	10.3	14.2	(T)	24.4	34.5
m13	7.5	0	N/A	45.7	Inf
		Maximum Load Truss Can Support:	33.5 oz ± 8.9 oz		
		Cost of truss:	$188		
		Theoretical max load/cost ratio in oz/$:	0.178		

The member to buckle first is highlighted in yellow.

Discussion and Conclusion

The rationale for our design was to optimize the cost of our truss while still being around the minimum amount of load that the truss should hold. We made the truss pretty simple by creating an extended base connected with many rods to the top portion. As shown in *Figure 1*, the top joints are connected by a couple of rods, one of them being diagonal and the other one perpendicular to the base. These members' formation makes a triangle, which is the best way to stabilize the design. We realized that those perpendicular members were zero-force. Hence, intuitively, we thought we had to take them away because they were not giving any benefit to the truss and just adding more cost to the design. But after some research about zero force members in designing trusses, we realized that they were still valuable for the structure's overall stability even though they were zero force.

The central aspect of the project that we think should be changed or revised is making the truss using acrylic rod and tape. When making the truss, we realized that although the rods were stable when using tape as joints, some were not perfectly aligned, and others were not wholly touching one from the other. To change this, we suggested that the truss building could be done with superglue instead. This would make sure that each rod is completely stuck one to the other, and it would be aesthetically more pleasing as a bonus.

Appendix

The discussion for the Hartford Roof Collapse took place in an online Zoom meeting on Thursday, December 2nd, 2021 from 4:00 PM to 5:30 PM. Joel was the acting chair while Taha was recording the time. We divided our discussion into four guiding questions (see *Planned Agenda* for more info). While each topic was covering a different topic concerning the Hartford Civic Center arena roof collapse, they all intertwined with each other allowing for each member in this group to contribute and correlate one point with another.

Acting Chair: Joel Akerman

Minute Taker: Taha H. Ababou

Planned Agenda

THURSDAY, DECEMBER 2ND, 2021

4:00 PM TO 4:15 PM - Read the *Hartford Civic Center Arena Roof Collapse* report

4:15 PM TO 5:10 PM - Discussion of the engineering failure topics

→ *(1) Discuss the use of computer programs in analysis and design.*

→ *(2) Discuss an appropriate safety factor to be used on your truss if it were to be used in a case where human life is at risk and report what maximum load is appropriate for the final design.*

→ *(3) Consider variability in materials and construction and any other factors you deem relevant.*

→ *(4) Discuss the ethical concerns of the Hartford collapse.*

5:10 PM TO 5:15 PM - 5 minute break time

5:15 PM TO 5:30 PM - Conclusion/Summary

Important points among each member

Initials	Important Notes
TA	- **(1&4)** - The space frame was not cambered. Computer analysis predicted a downward deflection of 13-in at the midpoint of the roof and an upward deflection on 6-in at the corners. These deflections were taken into account. - Because of these money-saving innovations, the engineers employed state of the art computer analysis to verify the safety of the building. - Once the frame was in its final position but before the roof deck was installed, its deflection was measured to be twice that predicted by computer analysis, and the engineers were notified. They, however, expressed no concern and responded that such discrepancies between the actual and the theoretical should be expected. - The engineers for the Hartford Arena depended on computer analysis to assess the safety of their design. Computers, however, are only as good as their programmer and tend to offer engineers a false sense of security. The roof design was extremely susceptible to buckling which was a mode of failure not considered by in that particular computer analysis and, therefore, left undiscovered.
JA	- **(1&4)** - These engineers relied too much on technology to verify their design. They valued money-saving innovations by employing state of the art computer analysis to verify the safety of the building. - To save time and money, the roof frame of the building was completely assembled on the ground. The inspection agency notified the engineers that it had found excessive deflections in some of the nodes, but nothing was done. This rises ethical concerns concering technology and whether their trust towards innovative products showcase ignorance or lack of ethical morality. - Engineers shall hold paramount the safety, health, and welfare of the public. - **(2)** - Finally, if the structure had been designed and built with more redundancy, the failure of a few members would not have resulted in such a catastrophic collapse.
RA	- **(4)** - Ethical engineers normally pay close attention to unexpected deformations and investigate their causes. They often indicate structural deficiencies and should be investigated and corrected immediately. However, engineers working on this project relied too much on computer programs neglecting warnings during construction and did not

	take the time nor effort to check their work. - **(2&3)** - A more traditional roof design would have been far more durable. A tube or I-bar configuration, rather than the cruciform shape of the rods, would have been much more stable and less prone to bending and twisting. Furthermore, if the horizontal and diagonal members had intersected at the same point, the bending stresses in these members would have been reduced.