Truss Project:
Final Design

Kelly Lam
Wenhao Cao
Xinyu Lei
Boston University

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Professor Albro

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Introduction

This project aims to design a truss capable of supporting a minimum load of 27.2oz and optimize it to support the highest load possible. Using MATLAB as a computational tool, we analyzed and optimized our engineered structure. The MATLAB portion helped us analyze reaction forces on the supporting joints and the internal forces that each truss member experiences. In the final design, we strive to maximize the load and minimize the load-to-cost ratio while taking uncertainty into consideration. After a few iterations, we have concluded that Design1 from the preliminary report gives us the lowest load-to-cost ratio and the max load, and therefore it remains the best design.

Procedure

Design1 in the preliminary design has proved to be our best design. We tried to remove the non-load-bearing member while also maintaining the ratio of members to joints with the equation (total members=total joints*2-3). We also tried different design variations by changing the members' directions to model more the Howe Truss than the Pratt Truss. However, after further analysis of the program, it was found that the maximum load of the new trusses was less than that of the original design.

Analysis

$F(L) = C * L^{-\alpha} \pm U_{fit}$ (equation 1)

C=3908.184 oz/in

L=7 in

$\alpha = 2.211$

U_{fit}=4.1 oz

Nominal Case:

$P_{crit}(L) = P_{nom} = 48.80$ (equation 2)

$P_{crit}(L) = W_{failure} \pm \Delta W$ (equation 3)

$48.80 = 58 \pm \Delta W$

ΔW= -9.20 oz

Strong Case:

$P_{crit}(L) = P_{nom} + \Delta P$ (equation 4)

ΔP=4.1oz

$P_{crit}(L)$= -5.10

$P_{crit}(L) = W_{failure} \pm \Delta W$

ΔW= -5.1oz

Weak Case:

$P_{crit}(L) = P_{nom} - \Delta P$ (equation 5)

$P_{crit}(L) = 44.71$

$P_{crit}(L) = W_{failure} \pm \Delta W$

ΔW= -13.30 oz

To account for the uncertainty of this design, we used equation 1 to find the P_{nom} , nominal buckling load for the critical member. The critical members are 7 inches long, as seen in

Figure 1. We used P_{nom} to calculate P_{crit} for each case using the general equation $P_{crit}(L) = P_{nom} \pm \Delta P$. Through equation 3 we were able to calculate ΔW, the uncertainty of failure weight. In order to decrease the uncertainty, we can either change the length of the member or $W_{failure}$. As we have found previously that we could not maximize our load, we could not change $W_{failure}$. As for the length of the member, the shortest length gave us the highest nominal buckling load and our critical member was already the minimum length possible, therefore we made no changes based on uncertainty. However, we would claim the maximum load for the design being 44.7 oz, accounting for the weak case.

Result

The final design consists of 13 members and 8 joints with a height of 7 inches and spans 30 inches wide. The inspiration comes from a Pratt truss with some modifications to ensure that it meets the requirements of the project.

Figure1: Final Truss Design - labeled pin (triangle), roller (circle), members (orange), joints (red), and highlighted critical member (purple)

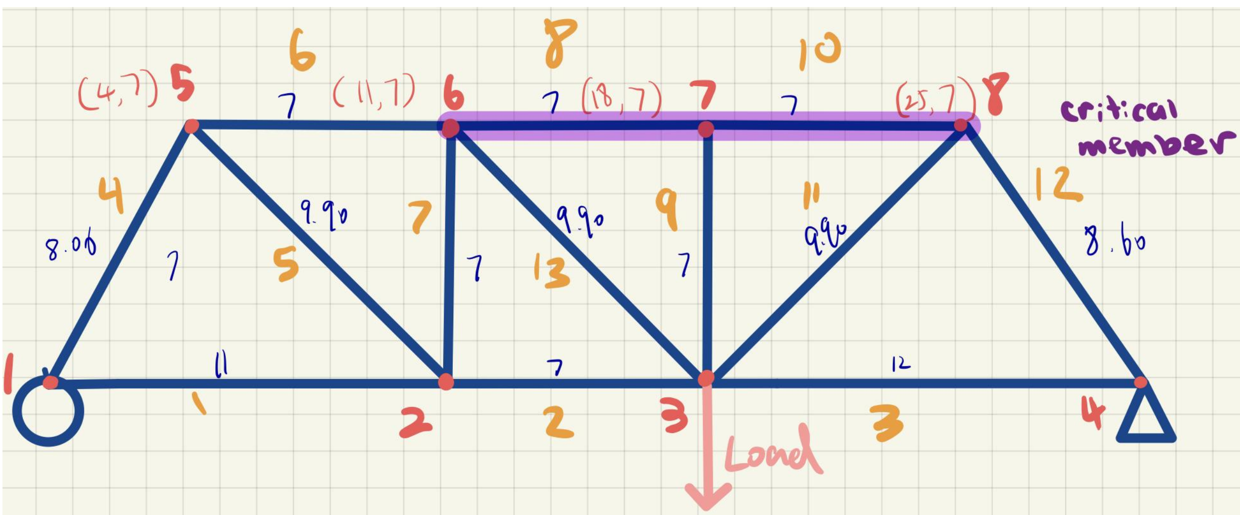

Table1: Table of Design 1's member number, its length, tension or compression, bucking strength, uncertainty, and maximum truss load.

Member_number	Member_Length_in	Tension_Compression	Buckling_Strength_oz	Uncertainty_oz	Forces_at_Maximum_Truss_Load_oz
1	11	"Tension"	NaN	NaN	13.356
2	7	"Tension"	NaN	NaN	36.729
3	12	"Tension"	NaN	NaN	25.043
4	8.0623	"Compression"	45.308	7.7712	26.92
5	9.8995	"Tension"	NaN	NaN	33.054
6	7	"Compression"	60.102	11.677	36.729
7	7	"Compression"	60.102	11.677	23.373
8	7	"Compression"	60.102	11.677	60.102
9	7	"Compression"	60.102	11.677	0
10	7	"Compression"	60.102	11.677	60.102
11	9.8995	"Tension"	NaN	NaN	49.582
12	8.6023	"Compression"	39.797	6.3165	43.085
13	9.8995	"Tension"	NaN	NaN	33.054

Figure2: Output of Computational Analysis

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\% EK301, Section A5, Group A: Kelly Lam, Xinyu Lei, Wenhao Cao, 11/11/2022.
Load: 58 oz
Member forces in oz
m1: 13.356 (T)
m2: 36.729 (T)
m3: 25.043 (T)
m4: 26.920 (C)
m5: 33.054 (T)
m6: 36.729 (C)
m7: 23.373 (C)
m8: 60.102 (C)
m9: 0.000 (C)
m10: 60.102 (C)
m11: 49.582 (T)
m12: 43.085 (C)
m13: 33.054 (T)
Reaction forces in oz:
Sx1: 0.000
Sy1: 35.060
Sy2: 23.373
Cost of truss: $191
Theoretical max load/cost ratio in oz/$: 0.30535
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Discussions and Conclusions

There were a lot of design iterations leading up to the final design in the report. We drew inspiration from other bridges and trusses such as the Warren, Waddell, and Pratt truss, designing with the limitations of the lengths being between 7 to 11 inches, a 30-inch span, budget, and a load-to-pin support span of 12 inches. We built up, we changed lengths, and we changed the directions of members. The most insightful was the code that led up to the design realization of zero force members that could be moved as well as realizing the critical member so that we could be more careful when constructing those members. When it was time to improve our preliminary design for the final design, we continued to change the lengths and move members based on the data only to have the original with the highest load. While building the truss, we've also come to realize the importance of uncertainties. As we have discussed in **Appendix.1**, without considering the uncertainties and claiming designs in an overconfident manner violates the ethics of being engineers and has significant consequences.

Elements of the project we would revise to better our designs were if we could find out how to incorporate shorter member lengths while within the limitations so that each member could have a higher buckling load. We would also find out how to support the critical member more so that there were one and not two critical members.

Appendix.1 Meeting Minutes

11/29/2022

Myles Standish

Hartford Roof Collapse

Participants: Kelly Lam, Xinyu Lei (Teresa), Wenhao Cao

Chair: Wenhao Cao **Minute Taker:** Kelly Lam

Agenda:

20 min Reading Hartford article

30 min Discussion of Article

20 min Conclusions

Kelly suggested how certain limitations given to us by the truss project manual helped us prevent design mistakes like the Hartford Roof Collapse, such as how the horizontal bars should intersect at the same point as the diagonal to make it less susceptible to buckling. The equation M=2J-3 was given to ensure that members intersected at the same point rather than in the middle of a member. Wenhao suggested that the computer program ran and was correct; it is merely a prediction and that other factors affect a design's stability. One of those was inputting the wrong frame weight and not factoring in torsional buckling, even though it was uncommon. Teresa also adds that their want for a cheaper design was one factor leading to its collapse. The need for peer review, basics like structural engineering, and a fragmented team. Concerns were pointed out multiple times, but due to the engineer's overconfidence in the program, the mistakes stayed in the execution. A part of the engineer's job is the safety of the people, and they should have been more concerned when a citizen brought up the deflection.

Moving forward, we concluded that everyone should be present and working on building the truss to ensure no execution errors. After the buckling lab, we know we should do our best not to bend the strip as it can deteriorate and make it more susceptible to breaking and buckling. We should watch the video on the construction and make sure our strips are cut as accurately as possible. The maximum load we should claim for the design is the lowest of the range of the uncertainty failure weight.