Group Project Computational Design of a structure

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ME 3164 – Section D35
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Introduction:

- The goal for this design was to construct a structure using Ansys to find the maximum load (in Newtons) it could withstand before failure.
- The constraints for the structure are as follows: made of balsa wood sticks whose height must exceed at least 20cm with a base that can span an area of 10X10 cm square. The Top square must be hollow and able to fit a 5 cm diameter by 20 cm long cylinder so that the hollow rectangle does not touch the cylinder. The force applied to the structure should be along the top square perimeter in the negative Y direction (-Y), defined by the coordinate system. The balsa wood sticks are to have an area with a cross-section of .3175X.3175 cm with any length. The Material properties of Balsa Wood are listed in the table below as the design should not best 19 grams.

Table 1: Material properties of Balsa Wood

Density, ρ	160 kg/m^3
Elastic Modulus, E	3.4 GPa
Poisson's Ratio, v	0.36
Tensile Yield Strength	20 MPa
Compressive Yield Strength	12 MPa

Method

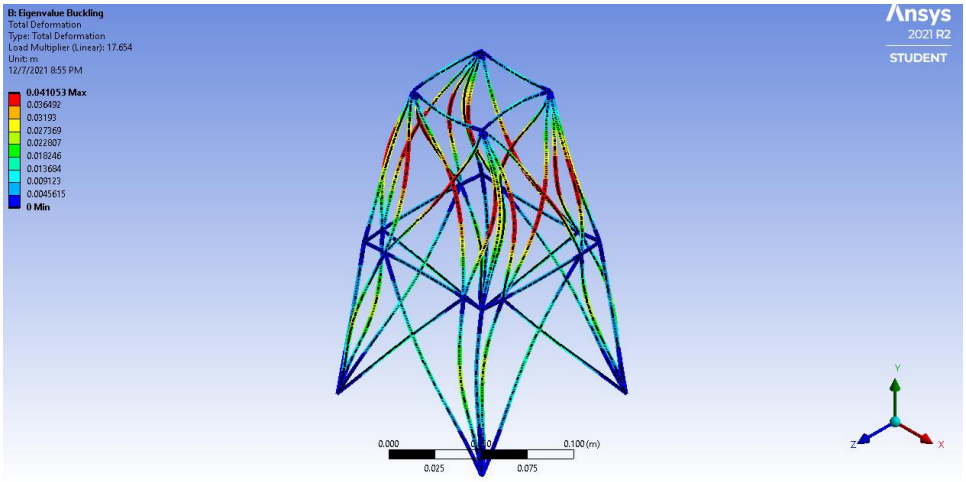
- Based on the constraints given to us we had to make sure that our structures fit around a 10 cm by 10 cm base without touching the base. Additionally, we to check that a 5 cm diameter cylinder could fit inside of our designs. We first made a square that would fit around the top of the cylinder and due to the cross-sectional dimensions of .3175 by .3175 cm, we had to verify that the top of our structure accounted for this and didn't allow the cylinder to fit. Next, we put the top of this square 20 cm up in the Y direction and have legs coming down at each of the corners to our base. Lastly, after making our design we checked in Ansys to confirm our structures weighed less than 19 grams.
- We plan to use optimization tools inside the Ansys software, to find the maximum load each structure can support before yielding or buckling, within the parameters of the balsa wood. For each optimization, we made sure that the maximum tensile strength was less than 20 MPa as well as the compressive strength was less than 12 MPa. We additionally tested for buckling which must have a deformation load multiplier greater than 1.
- The load is uniform on the top of the structure with a downwards force on the Y-axis. Additionally, we have fixed support at each of the legs on the base of the structure to allow the software to calculate buckling and yielding without sliding.

Intermediate designs

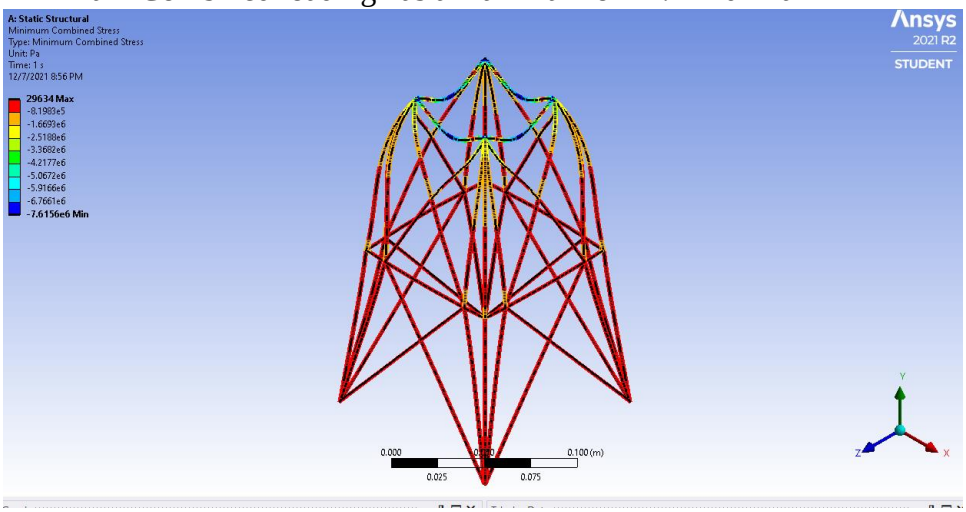
Design 1

- The maximum load it can support is 78.786 Newtons of force downwards with a 11X11 cm base with the top square being 5.25X5.25cm that weighs 8.08 grams.

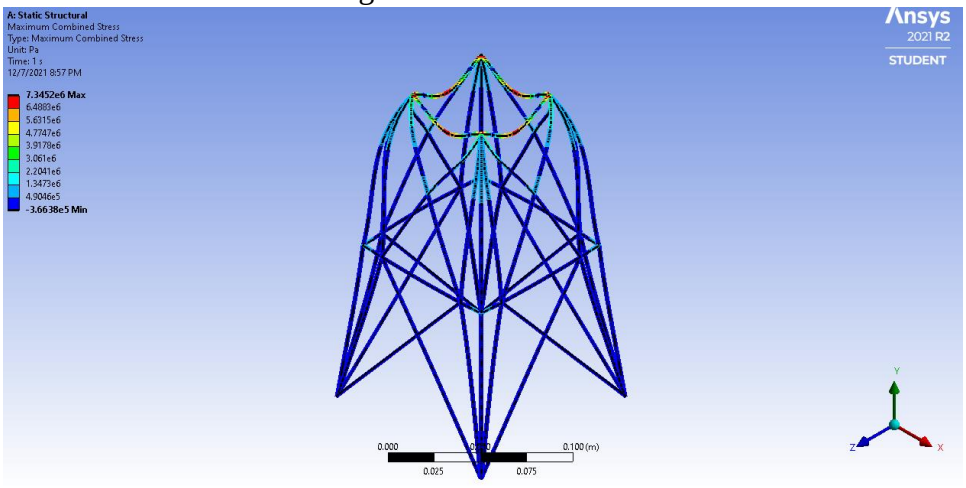
- Total deformation load multiplier 11.204

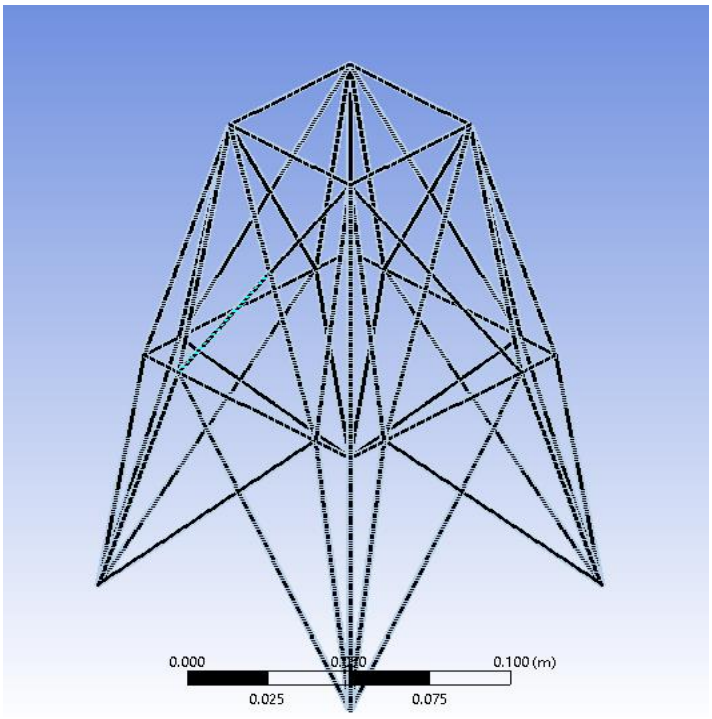


Minimum Combined loading has a maximum of –1.2E+07 Pa

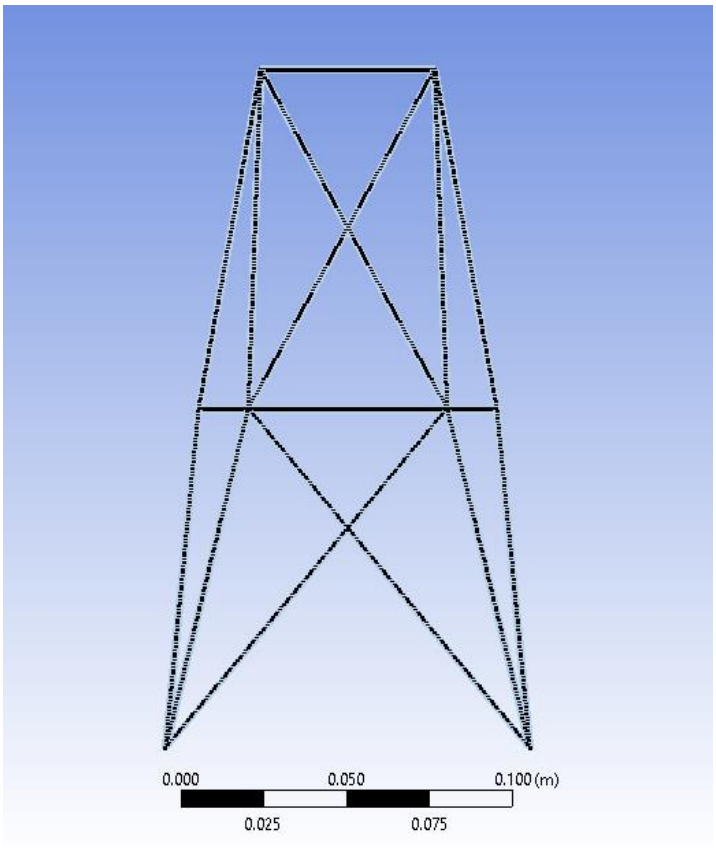


Maximum combined loading has a maximum of 1.1574E+07 Pa

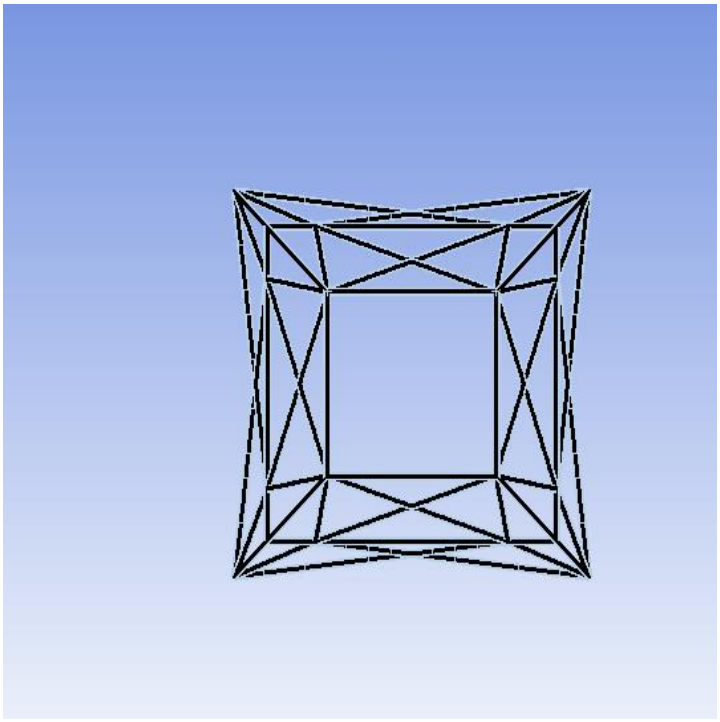


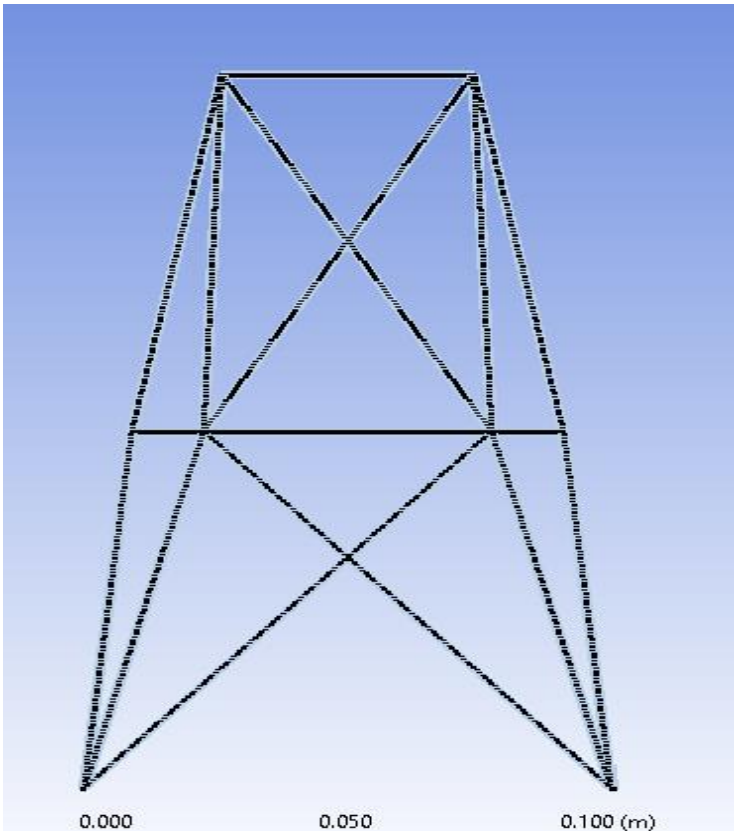


Isometric view



Side view


Top view



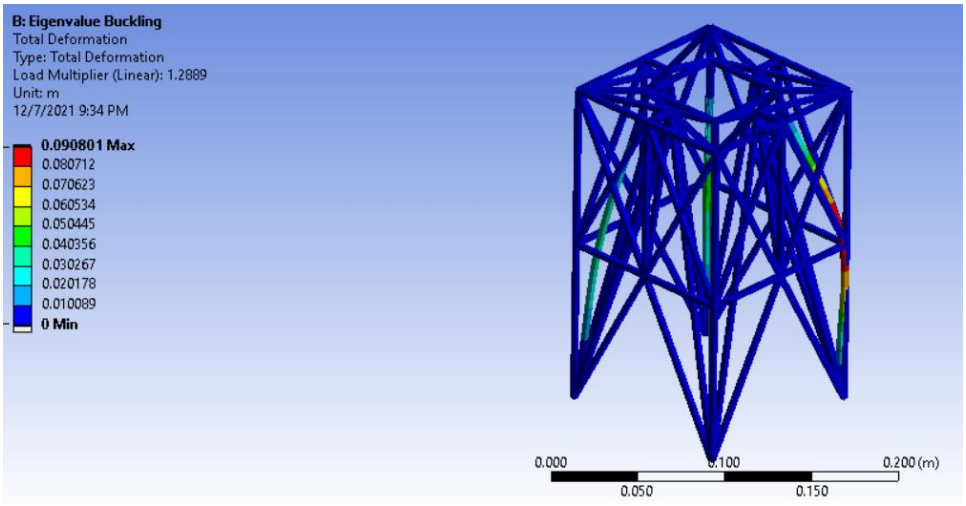
Front view

	A	B	C	D	E
1	Name	P4 - Force Y Component (N)	P5 - Minimum Combined Stress Minimum (Pa)	P6 - Maximum Combined Stress Maximum (Pa)	P8 - Total Deformation Load Multiplier
2	1	-220	-3.3509E+07	3.2319E+07	4.0122
3	2	-76	-1.1576E+07	1.1165E+07	11.614
4	3	-364	-5.5441E+07	5.3473E+07	2.4249
5	4	-148	-2.2542E+07	2.1742E+07	5.964
6	5	-292	-4.4475E+07	4.2896E+07	3.0229
7	6	-78.786	-1.2E+07	1.1574E+07	11.204
8	7	-178.63	-2.7207E+07	2.6241E+07	4.9414
9	8	-114.88	-1.7497E+07	1.6876E+07	7.6835
10	9	-62.302	-9.4893E+06	9.1524E+06	14.168
11	10	-78.786	-1.2E+07	1.1574E+07	11.204

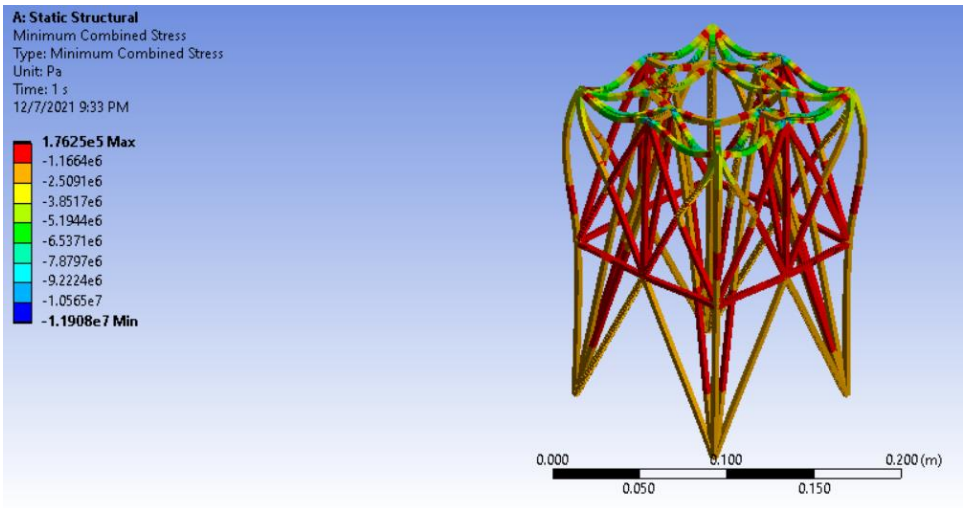
Design 2

- For this design, the structure has an 11 by 11 cm (about the length of the long edge of a credit card) base supports and a 5.3 by 5.3 cm (about half the length of the long edge of a credit card) square at the top to make sure the cylinder would fit. It has a square frame that goes up 20 cm and another square support at 10 cm. From there it has triangles across the whole structure for increased support. It also weighs 14.27 grams.

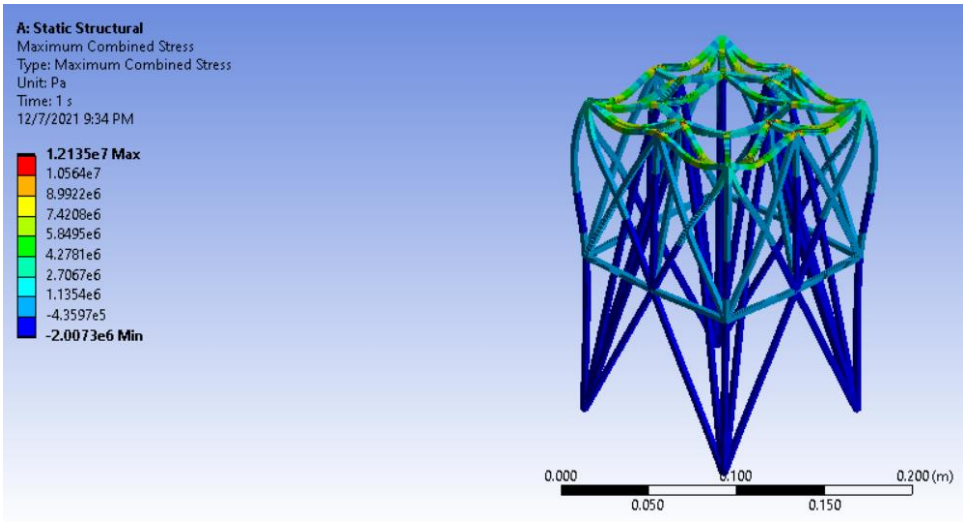
- The maximum load it can support is 319 Newtons of force downwards.



Total deformation developed across the structure with a force of 319 N downwards is 0.0908 mm with a minimum load multiplier of 1.28.

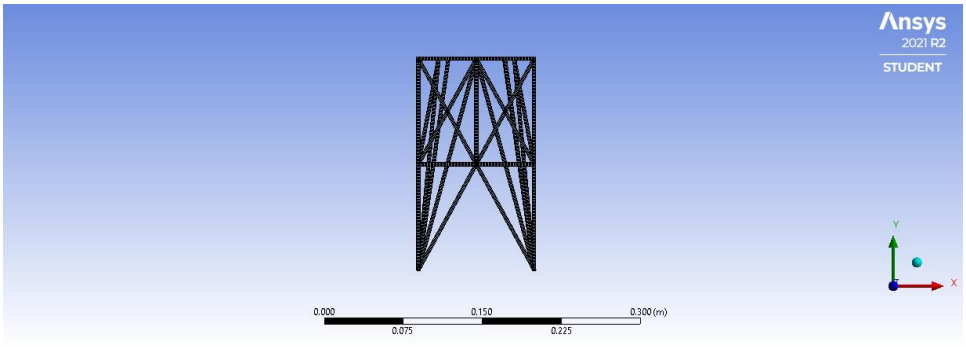


Maximum compressive stress developed across the structure with a force of 319 N downwards is 11.90 MPa.

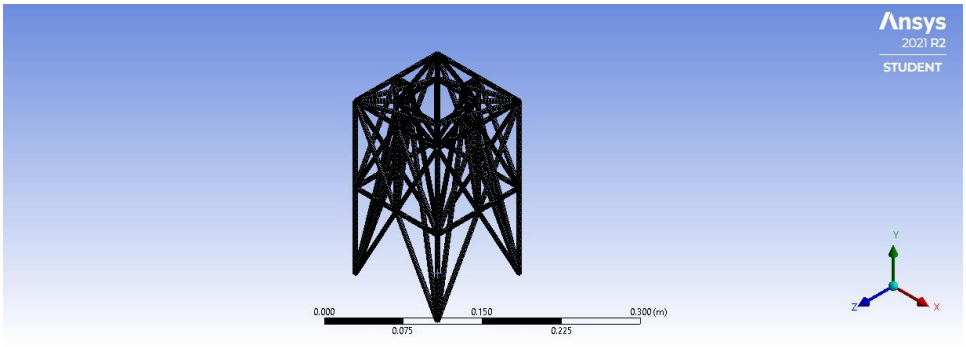


Maximum Tensile stress developed across the structure with a force of 319 N downwards is 12.13 MPa.

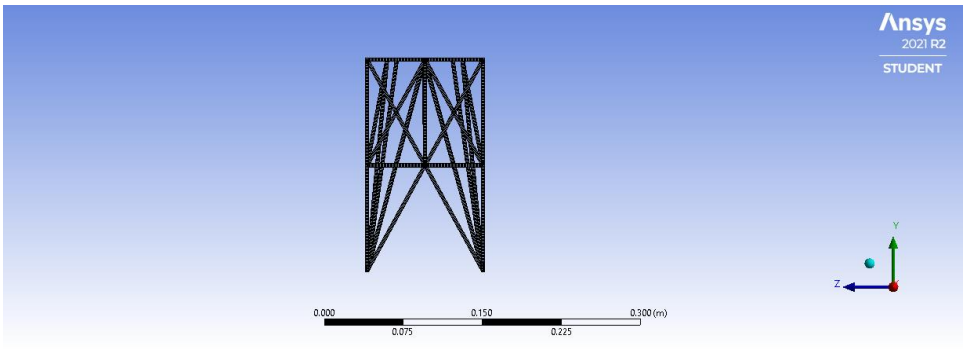
	A	B	C	D	E
1	Name	P5 - Force Y Component (N)	P2 - Minimum Combined Stress Minimum (Pa)	P3 - Maximum Combined Stress Maximum (Pa)	P4 - Total Deformation Load Multiplier
2	1	-330.83	-1.2349E+07	1.2585E+07	1.2428
3	2	-328.08	-1.2247E+07	1.248E+07	1.2532
4	3	-325.34	-1.2144E+07	1.2376E+07	1.2638
5	4	-322.59	-1.2042E+07	1.2271E+07	1.2745
6	5	-319.85	-1.1939E+07	1.2167E+07	1.2855
7	6	-317.1	-1.1837E+07	1.2063E+07	1.2966
8	7	-314.35	-1.1734E+07	1.1958E+07	1.3079
9	8	-311.61	-1.1632E+07	1.1854E+07	1.3195
10	9	-308.86	-1.1529E+07	1.1749E+07	1.3312
11	10	-306.12	-1.1427E+07	1.1645E+07	1.3431
12	11	-303.37	-1.1324E+07	1.154E+07	1.3553
13	12	-300.63	-1.1222E+07	1.1436E+07	1.3677
14	13	-297.88	-1.1119E+07	1.1332E+07	1.3803
15	14	-295.14	-1.1017E+07	1.1227E+07	1.3931
16	15	-292.39	-1.0914E+07	1.1123E+07	1.4062
17	16	-289.65	-1.0812E+07	1.1018E+07	1.4195
18	17	-286.9	-1.0709E+07	1.0914E+07	1.4331



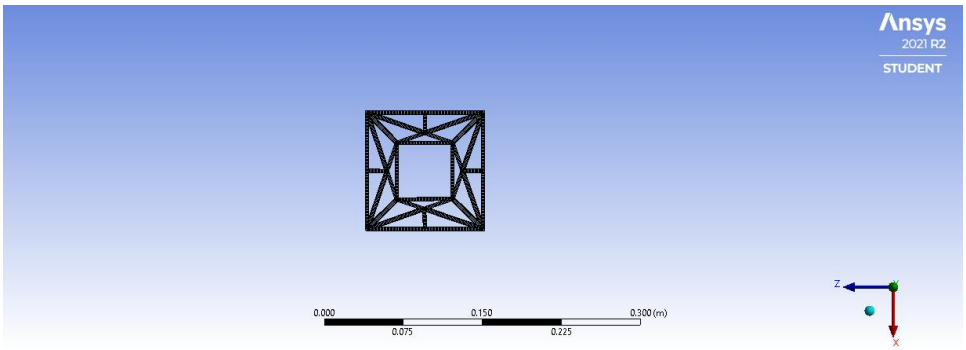
FRONT VIEW



ISOMETRIC VIEW



SIDE VIEW



TOP VIEW

Design 3

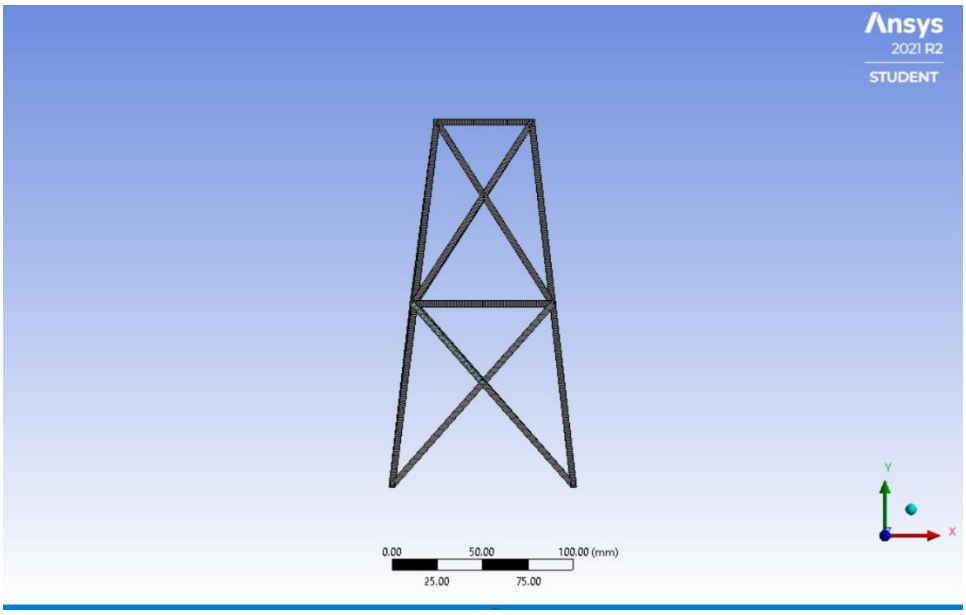
With a 10*10 cm base and 5.23*5.23 cm top, with 20cm between the plates, the maximum force this design can withstand is 196.43 N downwards without yielding or buckling.

Table of Design Points

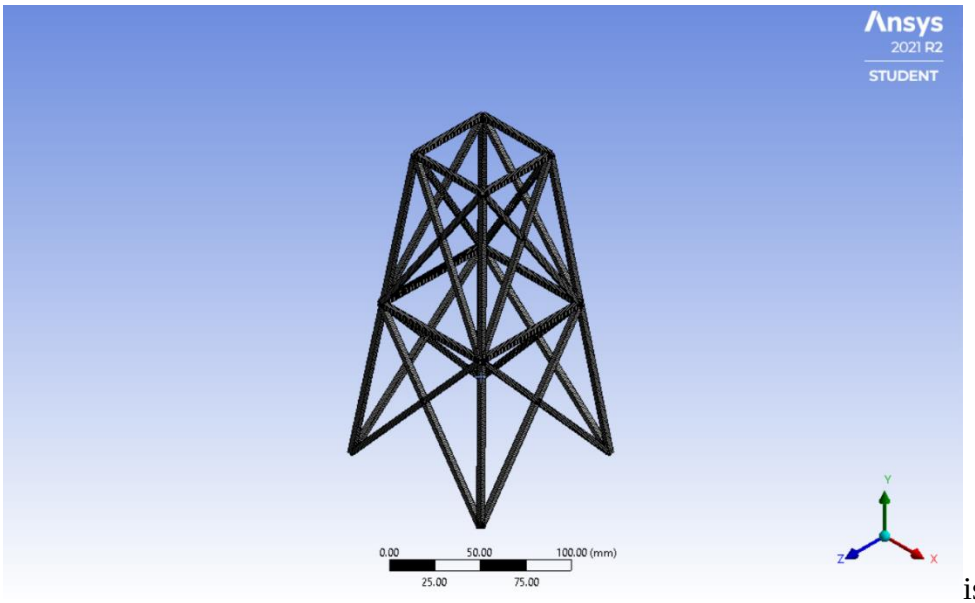
	A	B	C	D	E
1	Name	P4 - Force Y Component	P1 - Maximum Combined Stress Maximum	P2 - Minimum Combined Stress Minimum	P3 - Total Deformation Load Multiplier
2	Units	N	MPa	MPa	
3	DP 0 (Current)	-196.43	31.869	-31.642	1.0004

Table of Schematic C2: Optimization

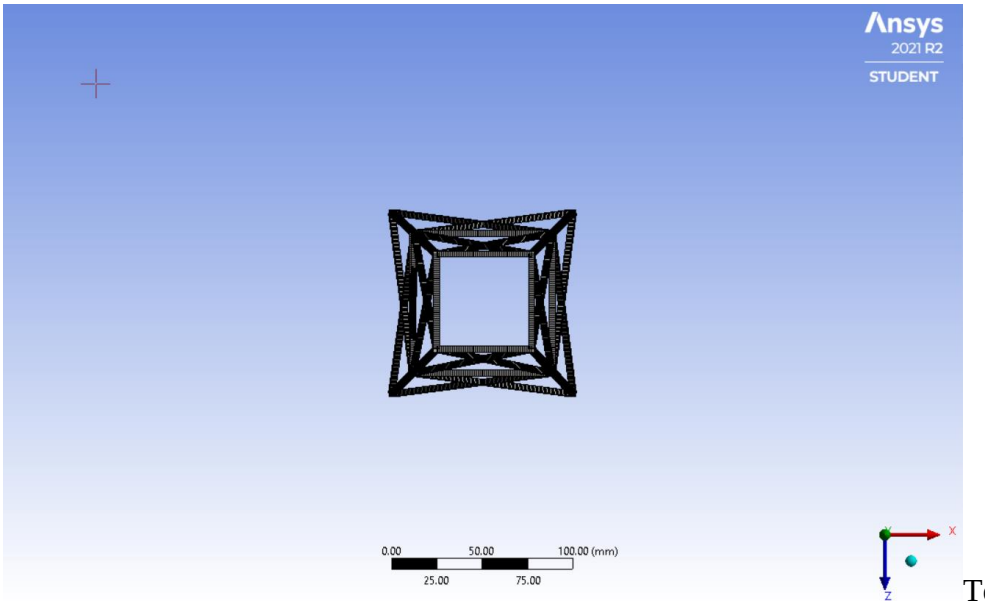
	A	B	C	D	E
1	Name	P4 - Force Y Component (N)	P1 - Maximum Combined Stress Maximum (MPa)	P2 - Minimum Combined Stress Minimum (MPa)	P3 - Total Deformation Load Multiplier
2	3	-632	102.54	-101.81	0.31093
3	5	-496	80.472	-79.898	0.39618
4	1	-360	58.407	-57.991	0.54585
5	7	-306.92	49.796	-49.441	0.64025
6	11	-262.19	42.538	-42.235	0.74948
7	4	-224	36.342	-36.083	0.87726
8	6	-208.08	33.759	-33.518	0.94438
9	16	-206.52	33.506	-33.267	0.95151
10	13 DP	-196.43	31.869	-31.642	1.0004
11	15	-196.41	31.866	-31.638	1.0005
12	18	-196.41	31.866	-31.638	1.0005
13	10	-191.97	31.146	-30.924	1.0236



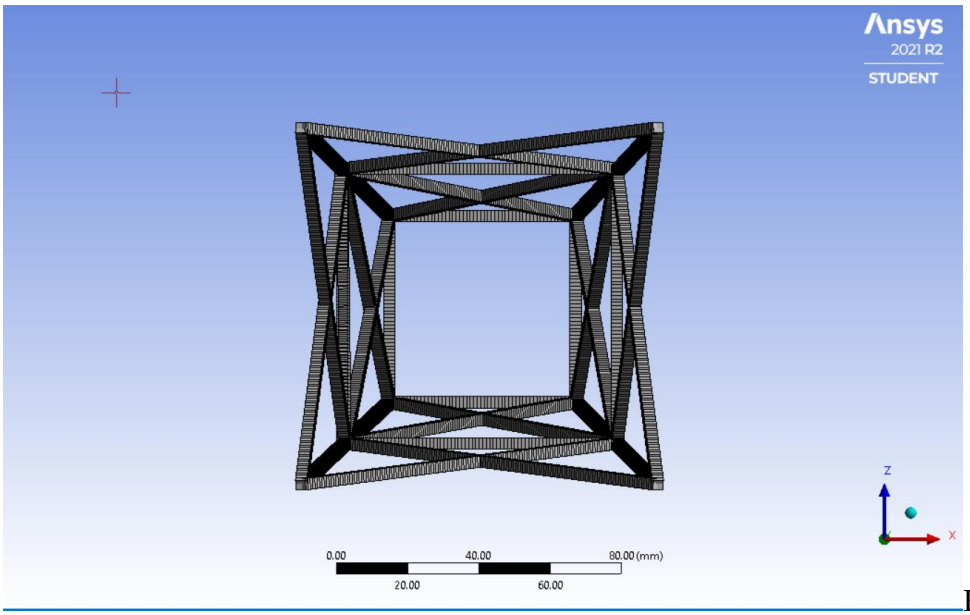
side view



isometric view

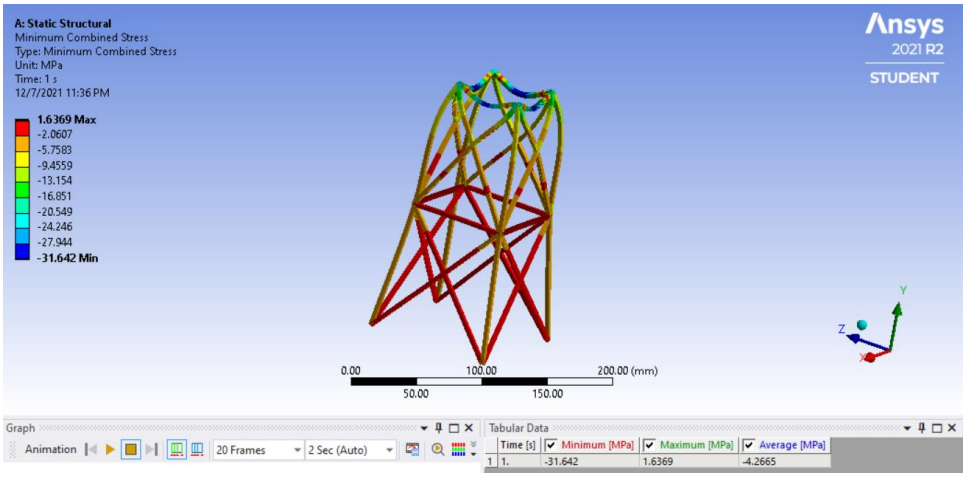


Top view

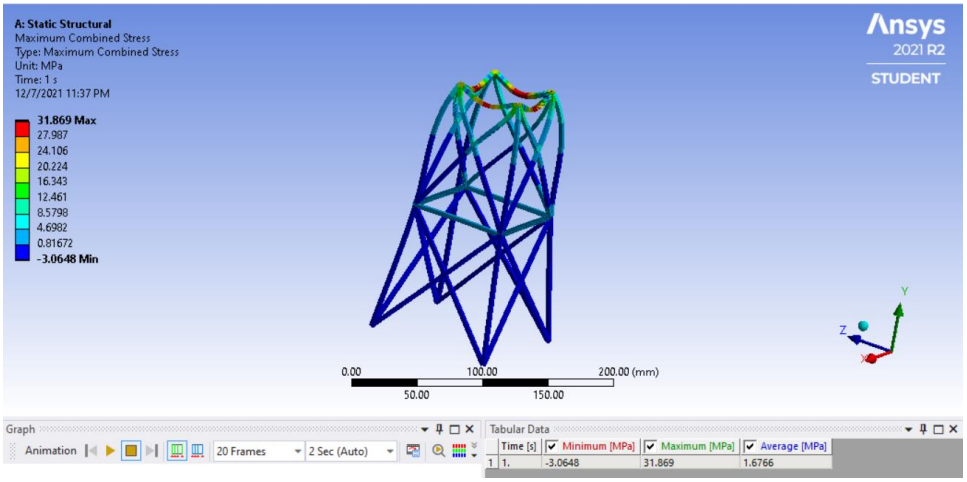


Bottom view

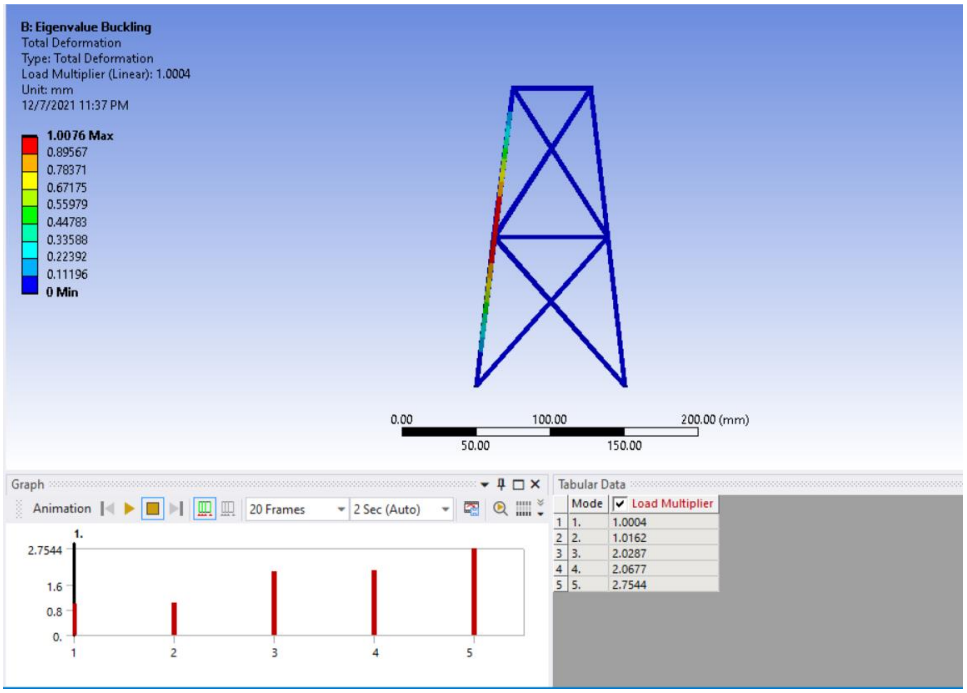
Maximum compressive stress developed across the structure with a force of 196.43 N downwards is 31.642 MPa.



Maximum Tensile stress developed across the structure with a force of 196.43 N downwards is 31.869 MPa.



Maximum deformation developed across the structure with a force of 196.43 N downwards is 1.0076 mm with a minimum load multiplier of 1.0004.



Final Design

- For the final design, we used design 2 as the base design as it had the highest load tolerance, 319.85 N downwards without buckling and yielding. We added some more base support to design 2, which further decreased the deformation in the structure. However, due to bending the structure could not support the original force and had to be lowered to 316.5 N downwards.

The material used was balsa wood.

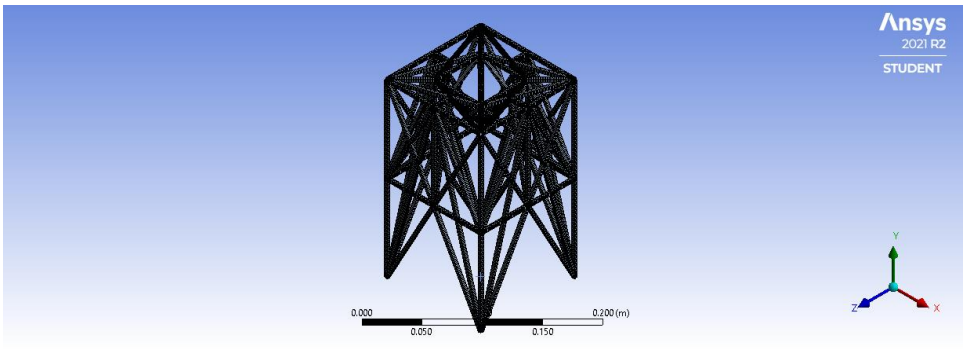
Details of "Line Body"

Treatment	None
Material	
Assignment	Balsa Wood
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Properties	
Volume	1.0415e+005 mm^3
Mass	1.6663e-002 kg
Length	10331 mm
Cross Section Area	10.081 mm^2
Cross Section IYY	8.4683 $mm^2 \cdot mm^2$
Cross Section IZZ	8.4683 $mm^2 \cdot mm^2$

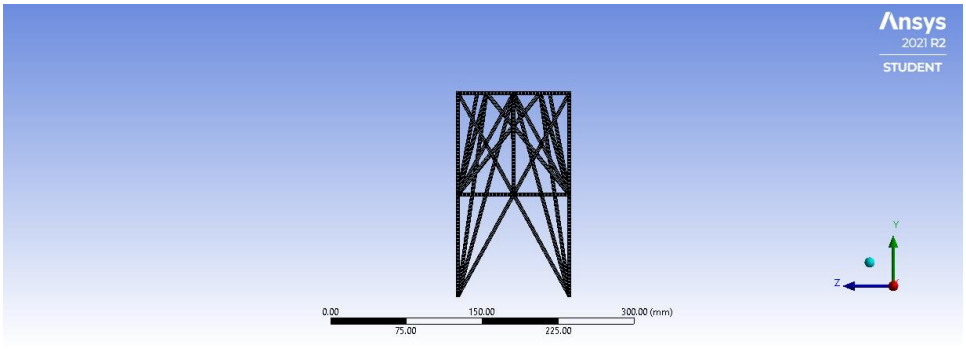
Reiteration of the force in y-direction due to yielding by bending stress.

B	C	D	E	F	G
P5 - Force Y Component (N)	P2 - Minimum Combined Stress Minimum...	P3 - Maximum Combined Stress Maximu...	P4 - Total Deformation Load Multiplier	P6 - Maximum Bending Stress Maximum ...	P7 - Minimum Bending Stress Minimum (Pa)
-320.6	-1.202E+07	1.2292E+07	1.8364	1.2156E+07	-1.2156E+07
-319.8	-1.199E+07	1.2261E+07	1.841	1.2126E+07	-1.2126E+07
-317.8	-1.1915E+07	1.218E+07	1.8526	1.205E+07	-1.205E+07
-316.5	-1.1867E+07	1.2134E+07	1.8602	1.2E+07	-1.2E+07
-316.5	-1.1867E+07	1.2134E+07	1.8602	1.2E+07	-1.2E+07
-315	-1.181E+07	1.2077E+07	1.869	1.1944E+07	-1.1944E+07
-313.86	-1.1768E+07	1.2033E+07	1.8759	1.19E+07	-1.19E+07
-312.2	-1.1706E+07	1.1969E+07	1.8858	1.1838E+07	-1.1838E+07
-309.4	-1.1601E+07	1.1862E+07	1.9029	1.1731E+07	-1.1731E+07

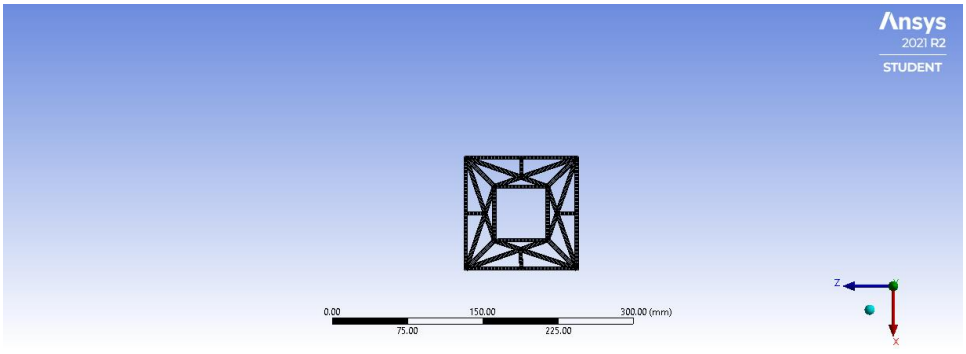
Design views:



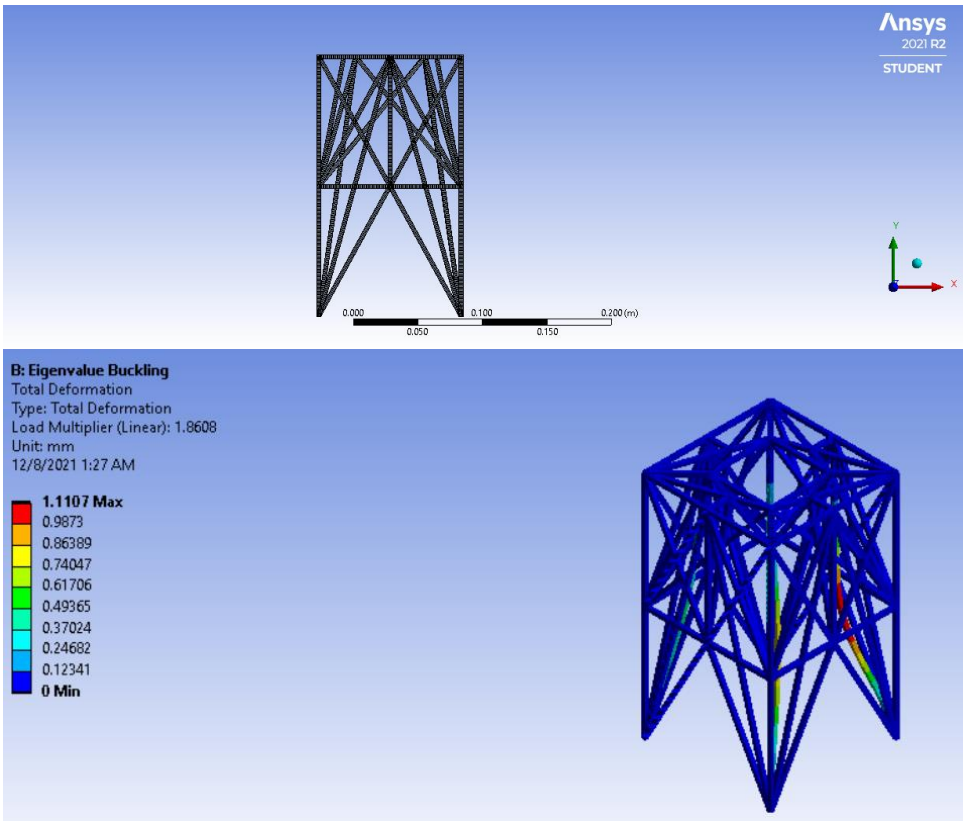
Isometric View



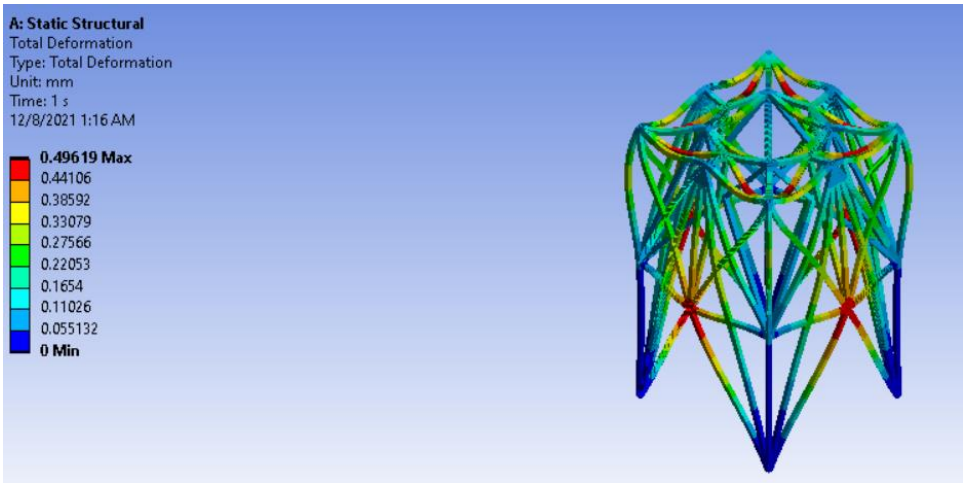
Side view



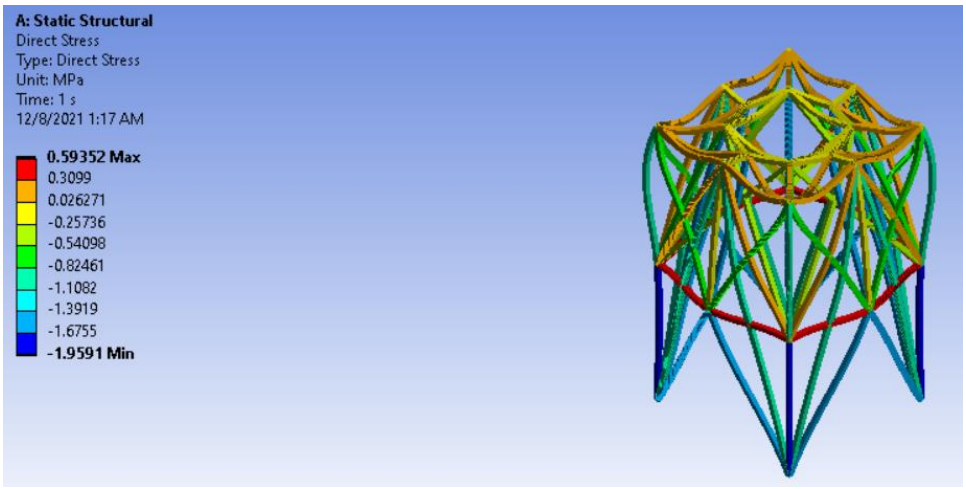
Top View



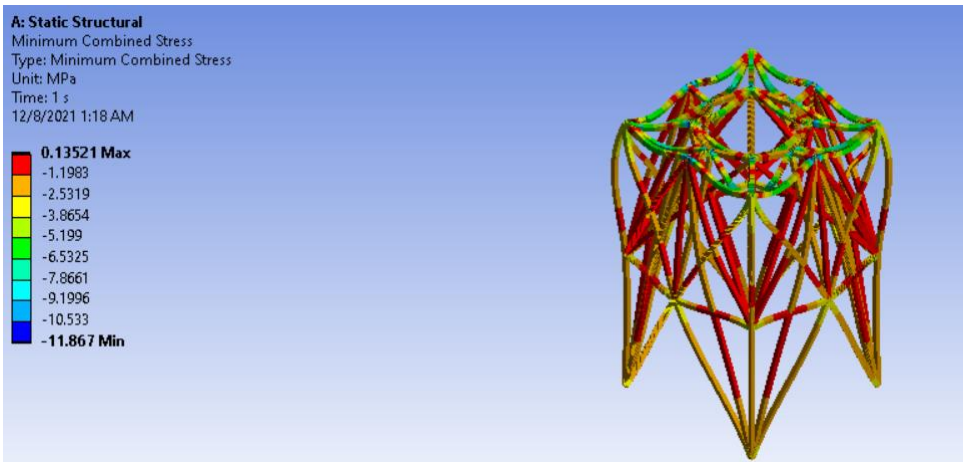
Maximum deformation developed across the structure with a force of 316.5 N downwards is a minimum load multiplier of 1.86.



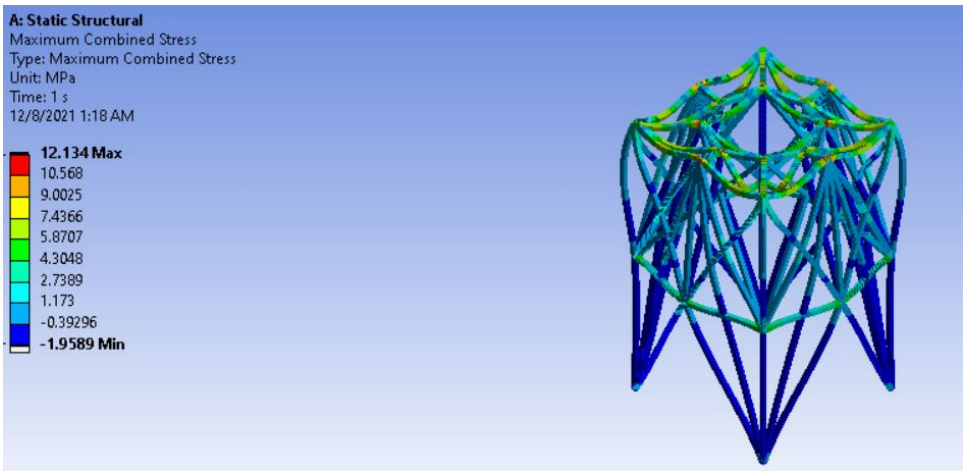
Maximum deformation developed across the structure with a force of 316.5.N downwards is 0.496 mm.



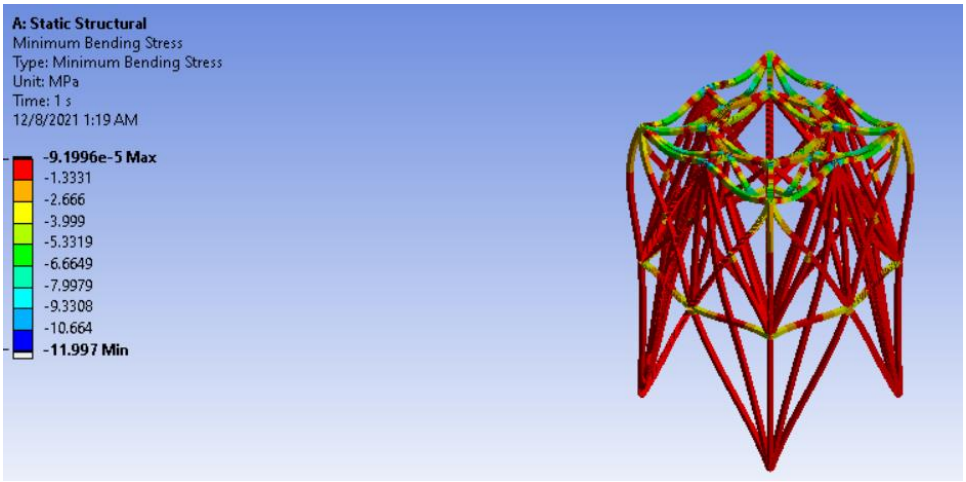
The maximum direct stress across the structure with a force of 316.5 N downwards is 0.59352 MPa.



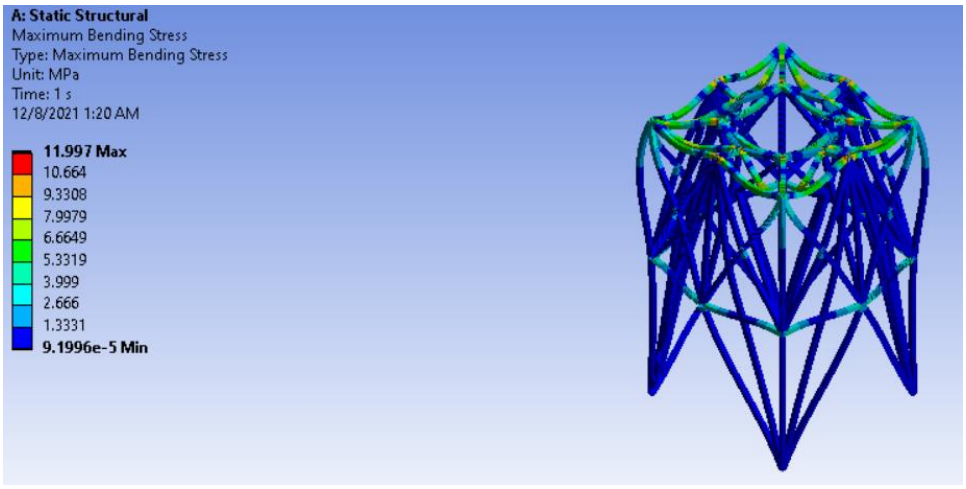
Maximum compressive stress developed across the structure with a force of 316.5 N downwards is 11.867 MPa.



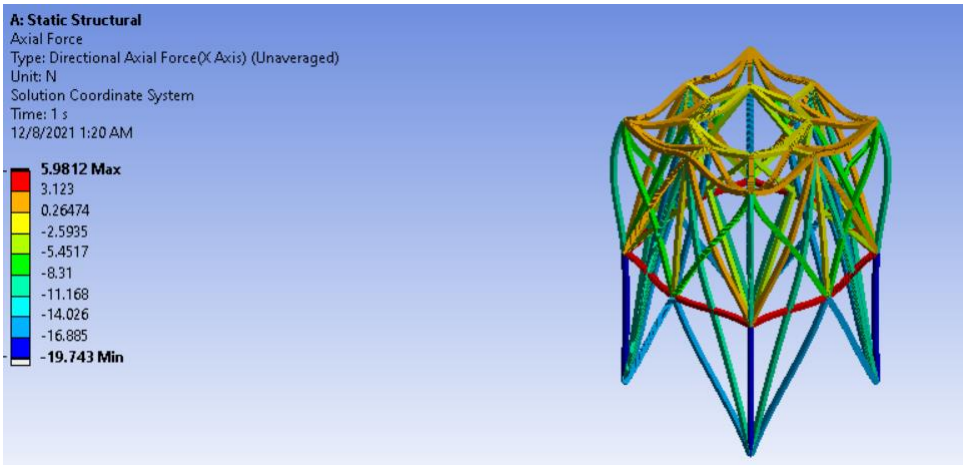
Maximum Tensile stress developed across the structure with a force of 316.5 N downwards is 12.134 MPa.



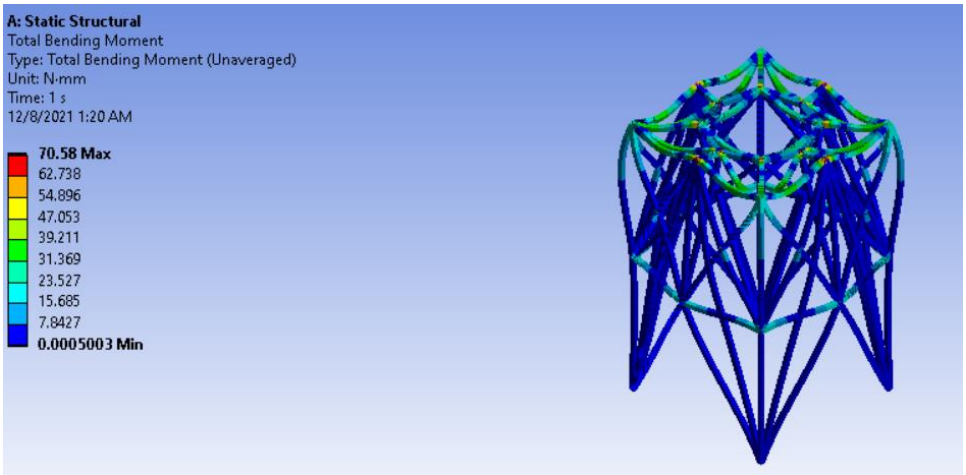
Maximum compressive bending stress developed across the structure with a force of 316.5 N downwards is 11.997 MPa.



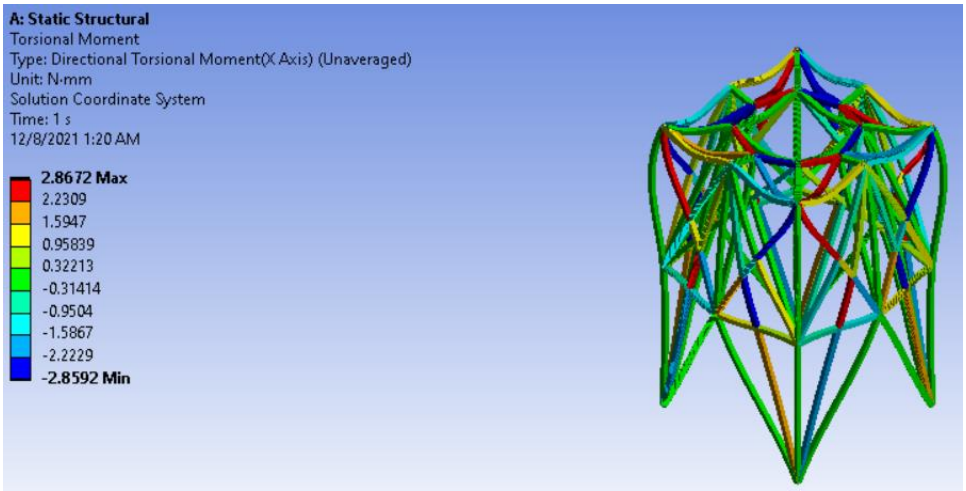
Maximum Tensile Bending Stress developed across the structure with a force of 316.5 N downwards is 11.977MPa.



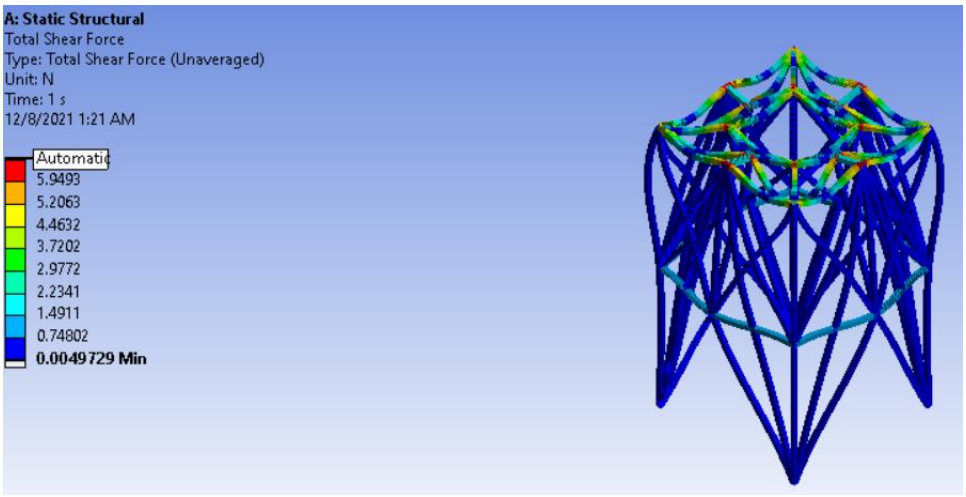
Maximum directional Axial Force developed across the structure with a force of 316.5 N downwards is -19.743 N (x-direction).



Maximum Total Bending moment developed across the structure with a force of 316.5 N downwards is 70.58N*mm.



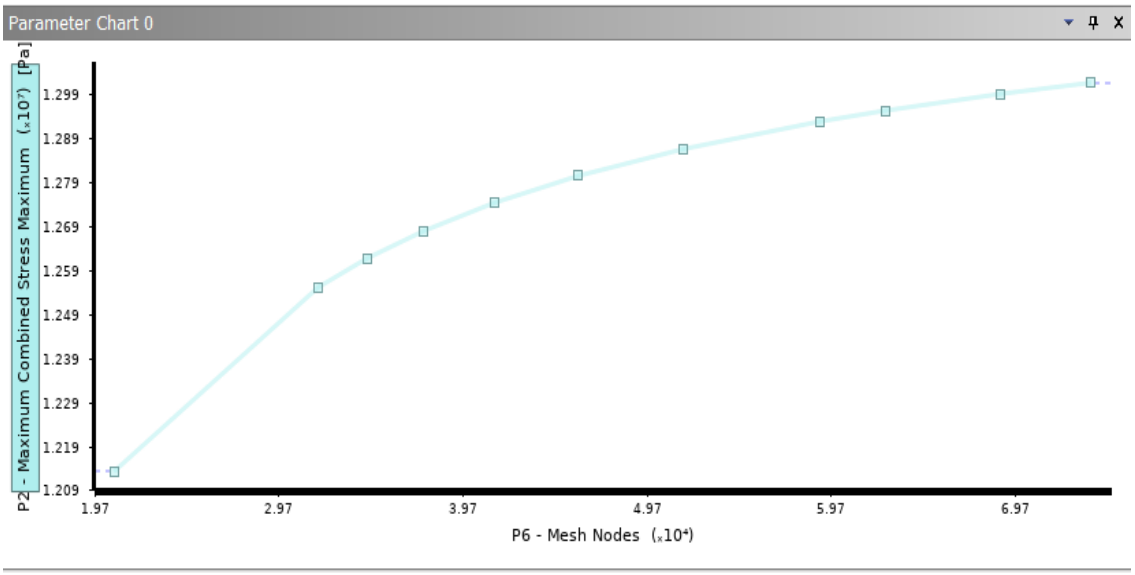
The maximum torsional moment developed across the structure with a force of 316.5 N downwards is 2.86 N*mm.



Maximum Total shear force developed across the structure with a force of 316.5N downwards is 6.692 N.

-Mesh convergence

(Mesh Nodes Vs. Maximum Combined Stress Maximum)



The graph above (Mesh Nodes Vs. Maximum Combined Stress Maximum) flattens off towards a finite value making the behavior of the mesh an independent solution.

- **Number of Nodes and Elements**

Outline of All Parameters

	A	B	C	D
1	ID	Parameter Name	Value	Unit
2	Input Parameters			
3	Static Structural (A1)			
4	P1	Force Y Component	-316.5	N
5	P5	Mesh Element Size	0.001	m
*	New input parameter	New name	New expression	
7	Output Parameters			
8	Static Structural (A1)			
9	P2	Maximum Combined Stress Maximum	1.2134E+07	Pa
10	P3	Minimum Combined Stress Minimum	-1.1867E+07	Pa
11	P6	Mesh Nodes	20739	
12	P7	Mesh Elements	10423	
13	Eigenvalue Buckling (B1)			
14	P4	Total Deformation Load Multiplier	1.8602	
*	New output parameter		New expression	
16	Charts			
17	Parameters Chart			

The number of Mesh Nodes is 20739 and the number of Mesh Elements is 10423.

Declaration

Zander Goodwin: Design 1 – Intro-Mesh convergence- Number of nodes/elements

Colton Hysmith: Design 2 - Method – Table 1 - Final design pics/descriptions

Pinak Bhuban: Design 3 – Cover page – Final design explanation/descriptions - References

Reference:

- Texas Tech university. (n.d.). *FEA lab handouts 1-9*. Retrieved December 8, 2021.