Maryam Hakimzadeh **Due: 3/20/2024**

Overall Objective

The objective is to design a beam-based tower within a 5m by 5m space, supporting a 36,000 kg top mass at 20m height, its weight, and wind load, with a 3600 kg mass budget. The design will use two sizes of square, hollow cross-sections, aiming for a safety factor of 5 in stress analysis and a minimum buckling load of 10.

Assumptions

Thermal effects are not considered.

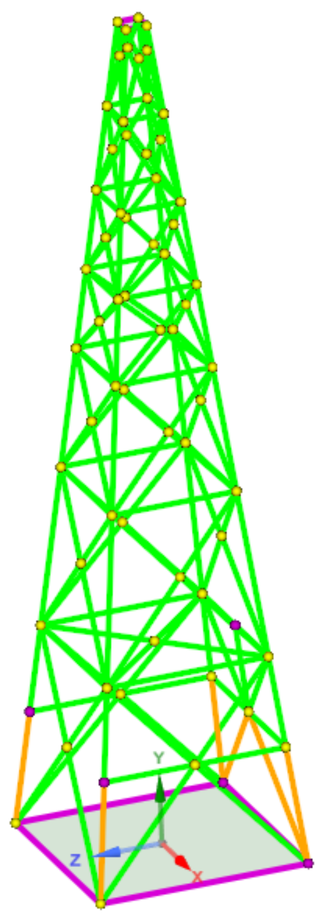
The analysis is based on linear elasticity.

Stress risers near the frictionless support are ignored.

Beam theory has been utilized for analysis.

Geometry

Considering the geometric and structural constraints, the proposed tower structure is designed as follows:



Material Data

Structural steel has been used from the default material in Ansys Mechanical.

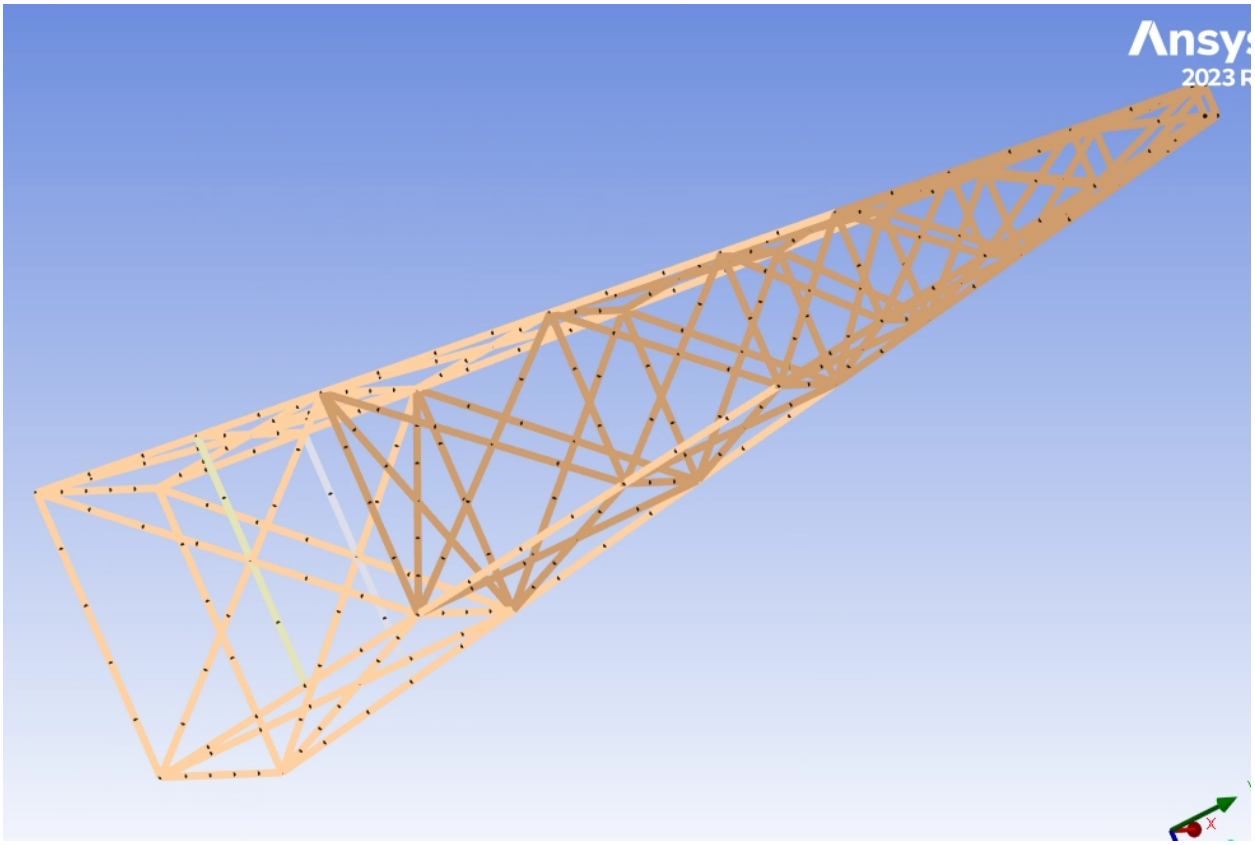
Boundary Conditions

The tower is subjected to a dead load of 36,000 kg at its apex, a lateral wind load of 9,000 N, and must support its self-weight. Also, the tower is fixed at the bottom.

The boundary conditions utilized in the ANSYS Mechanical analysis are detailed in the appendix.

Mesh convergence study:

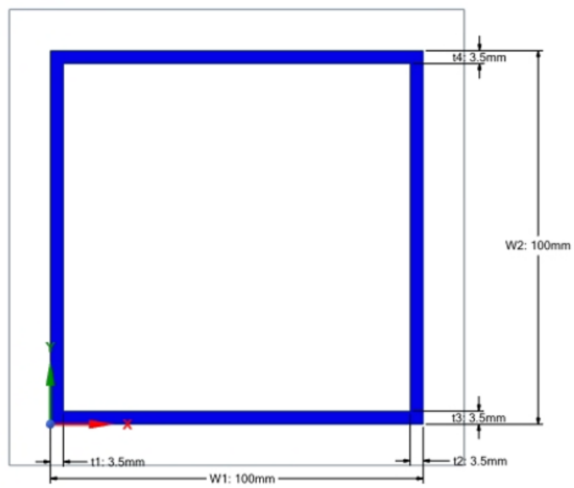
Safety factor of 5 is incorporated into the tower's design, allowing the use of the default mesh to enhance calculation efficiency. Consequently, a mesh convergence study was deemed unnecessary. The mesh configuration is illustrated below:



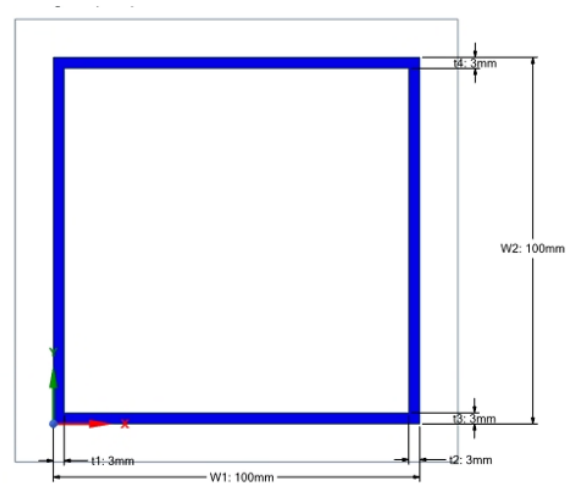
Results

Below shows the summary of results for my design, including mass of the structure, safety factors, and cross sections:

Mass(Kg)	3804
FS_{stress}	4.05
$FS_{buckling}$	11.10

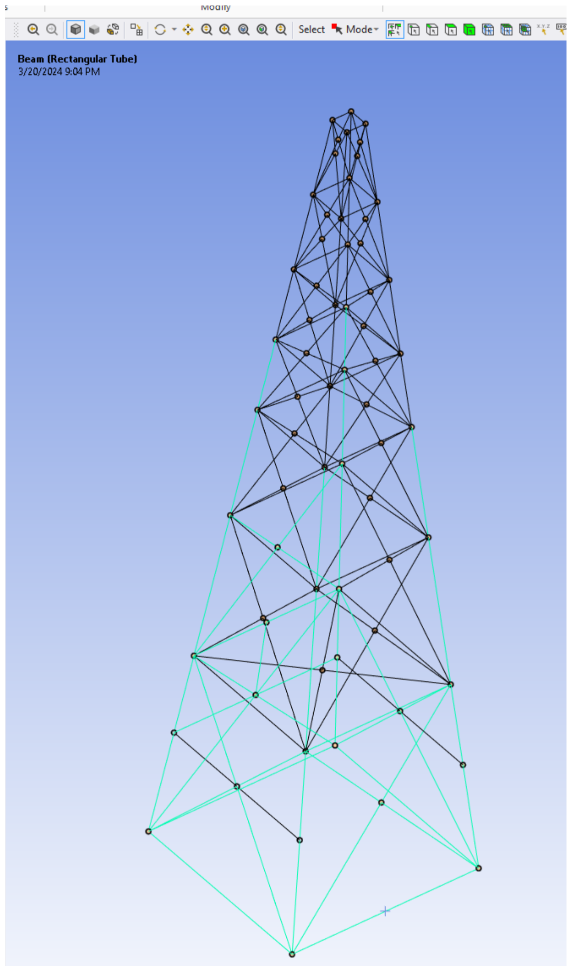


Large cross section
(48 members)



Small cross section
(138 members)

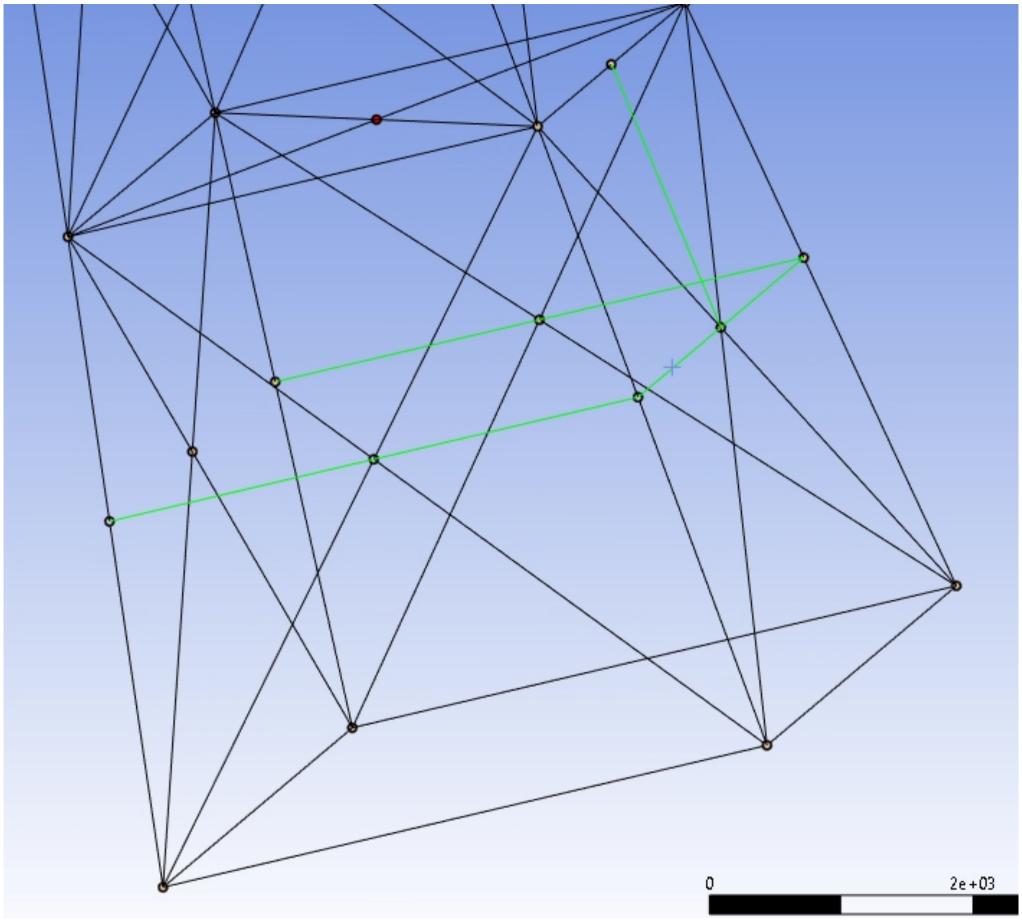
In below figure, beams with large cross sections are indicated in blue, while the beams with small cross section are indicated in black:



Design Evolution:

Initially, a uniform 5x5 square cross-section was selected for the tower's entire height. However, subsequent analyses indicated that achieving the desired safety factors for stress and buckling within the mass budget was unfeasible. Consequently, I transitioned to a tower design with variable cross-sections along its height to meet safety requirements and adhere to the mass constraint.

The introduction of braces proved beneficial for enhancing stability against horizontal wind loads and buckling resistance. Further analysis revealed that buckling was a critical concern in the tower's lower region, leading to reduced safety factors. To fortify the structure, additional beams were integrated internally, connecting two walls, which are depicted in green:



In the tower's design, thicker cross-section beams were employed in the lower parts to enhance strength and stability, whereas thinner cross-section beams were utilized in the upper regions to optimize the structure's weight and material efficiency.

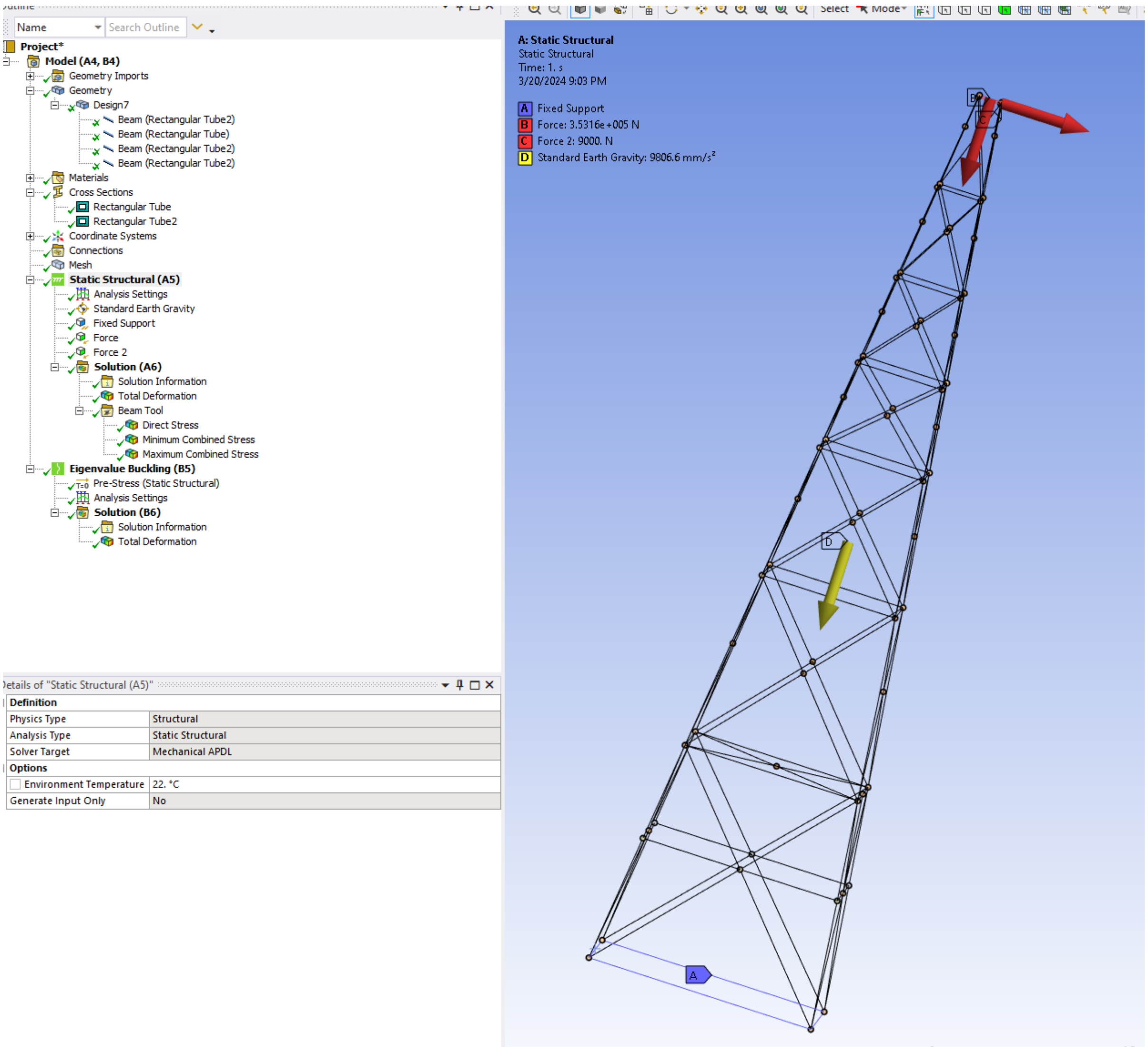
Additionally, it was hypothesized that triangular cross-sections might yield a more efficient design, but due to time constraints, this possibility was not explored further.

Conclusions

The analysis successfully designed a tower supporting a 36,000 kg top mass within specified constraints, achieving a buckling safety factor of 11.10 but slightly missing the stress safety target with 4.05. The iterative approach, utilizing variable cross-sections and strategic bracing, effectively balanced structural integrity with the mass budget, demonstrating the tower's capability to withstand the designated loads and conditions.

Appendix:

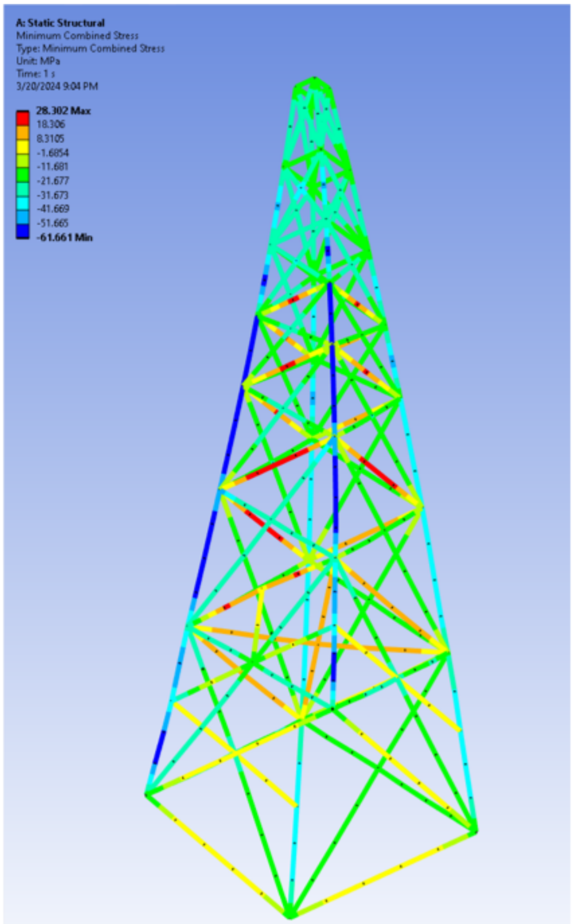
Boundary conditions in Ansys mechanical are shown below:

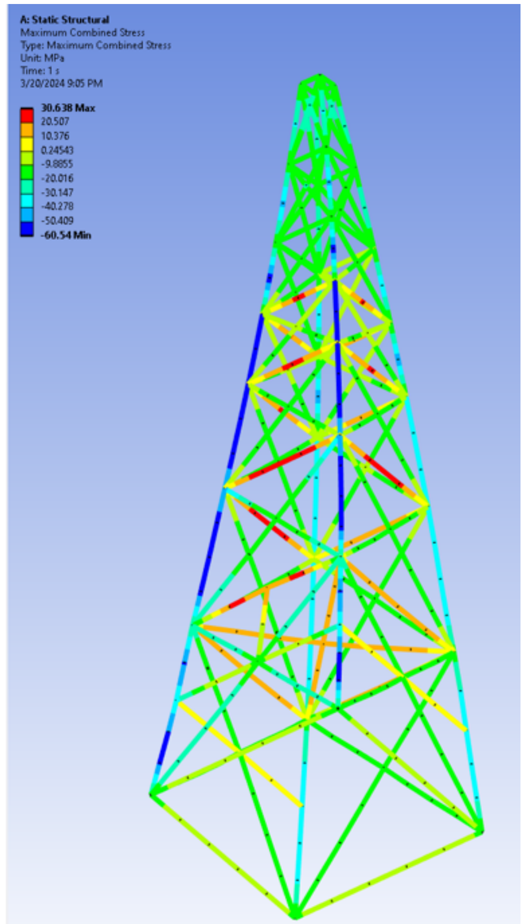


The mass of the structure is shown below:

Bounding Box	
Properties	
Volume	4.8455e+008 mm^3
Mass	3803.7 kg
Statistics	

The results from the beam Tool are presented with the minimum structural stress analysis displayed on the left and the maximum structural stress analysis on the right.





The outcomes of the buckling analysis are illustrated below: