# 24-650 Applied Finite Element Analysis

# Assignment 5

submitted by

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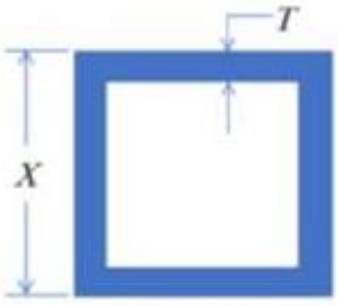
## Objective

The goal of this assignment is to perform a design of a tower that will support a specific amount of load at the top. The load contains a mass of 36,000 kg, and a horizontal wind load of 9,000N. The height is 20m and the width is 5m.

## Assumptions and Loading Conditions

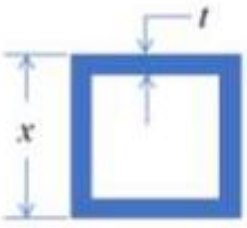
1) Deadweight 36,000kg at the top.
2) Wind load 9000N at the top.
3) Material is structural steel, Young's Modulus is 2000GPa, Poisson's ratio is 0.3, density 7850kg/m3, and yield strength is 250MPa.
4) Two types of beam with two cross-section design are applied, indicated below:

| | |
|---|---|
| **Mass (kg)** | **3599.4** |
| **$FS_{stress}$** | **5.807** |
| **$FS_{buckling}$** | **11.38** |




Large Cross Section

146 Elements




Small Cross Section

171 Elements

X = 150mm

T = 4mm

x = 55mm

t = 3mm

# Model and Geometry

The final design structure and geometry are indicated below:

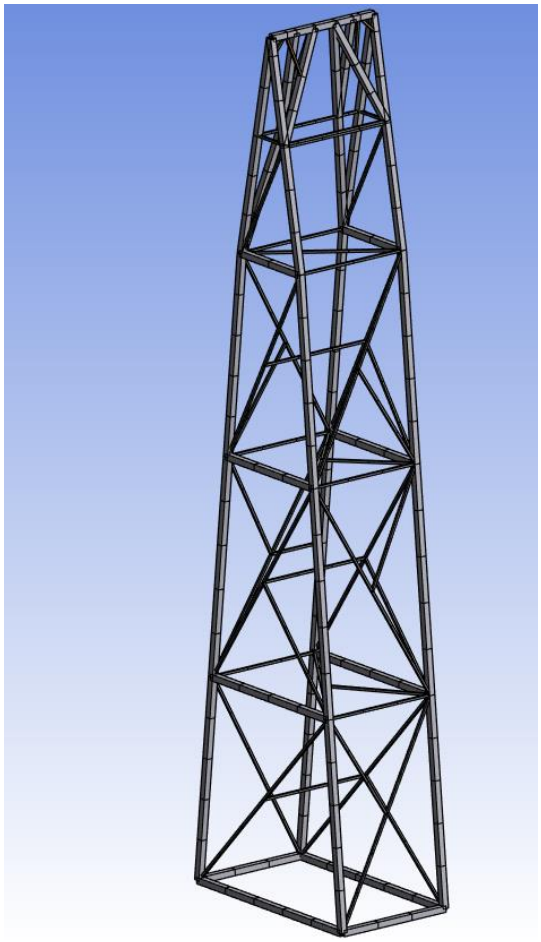


Figure 1. The Model (317 Elements)

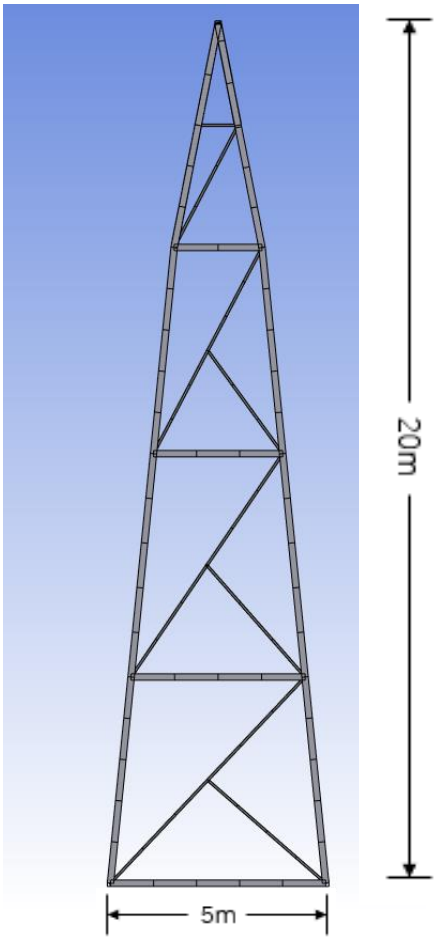



Figure 2. Dimension

| Definition | |
|---|---|
| Source | E:\GitHub_repos\FEA_projects\HW5\hw5_files (2)\hw5... |
| Type | SpaceClaim |
| Length Unit | Meters |
| Element Control | Program Controlled |
| Display Style | Body Color |
| **Bounding Box** | |
| **Properties** | |
| Volume | 0.45852 $m^3$ |
| Mass | 3599.4 kg |
| Scale Factor Va... | 1. |
| 2D Tolerance | Default (1.e-005) |
| **Statistics** | |
| **Update Options** | |
| **Basic Geometry Options** | |
| **Advanced Geometry Options** | |

Figure 3. Total Mass of **3599.4kg**

# Boundary Conditions (Part A)

The boundary conditions of support on four side and radial are indicated below, and all mesh settings are default.

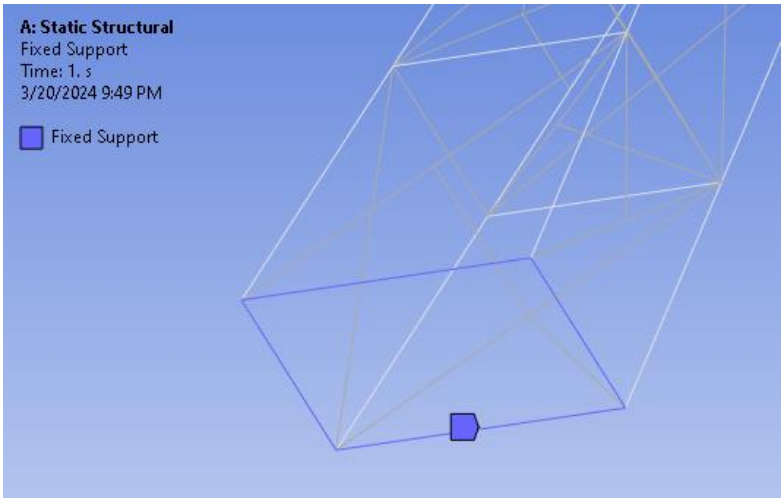
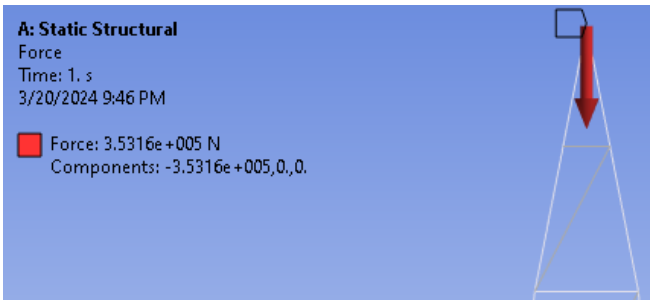



Figure 3. BCs

Force BCs are indicated below:

| Scope | |
|---|---|
| Scoping Method | Geometry Selection |
| Geometry | 7 Edges |
| **Definition** | |
| Type | Force |
| Define By | Components |
| Applied By | Surface Effect |
| Coordinate System | Global Coordinate System |
| X Component | -3.5316e+005 N (ramped) |
| Y Component | 0. N (ramped) |
| Z Component | 0. N (ramped) |
| Suppressed | No |




| Scope | |
|---|---|
| Scoping Method | Geometry Selection |
| Geometry | 7 Edges |
| **Definition** | |
| Type | Force |
| Define By | Components |
| Applied By | Surface Effect |
| Coordinate System | Global Coordinate System |
| X Component | 0. N (ramped) |
| Y Component | 0. N (ramped) |
| Z Component | -9000. N (ramped) |
| Suppressed | No |

# Results (Part A)

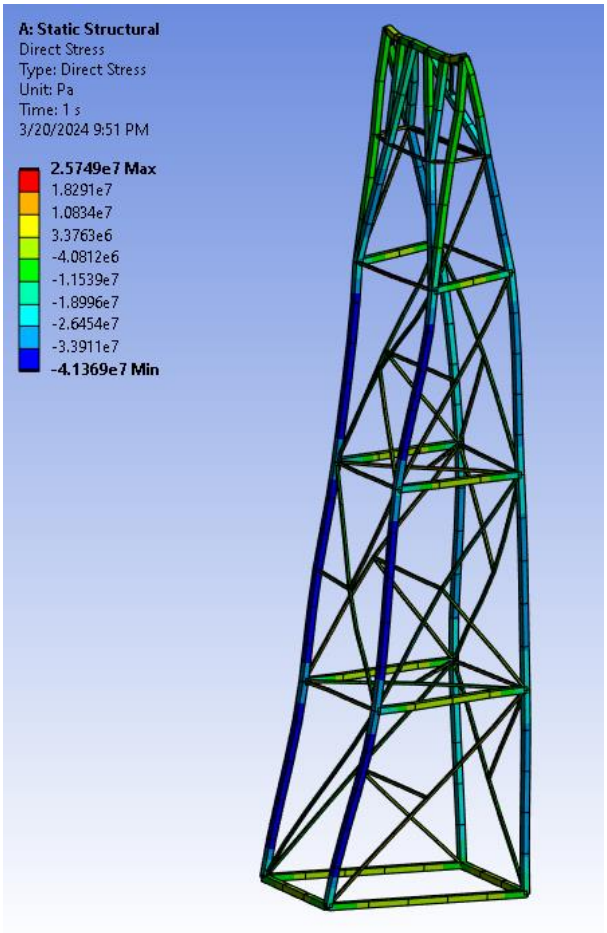



Figure 4. Min Combined Stress

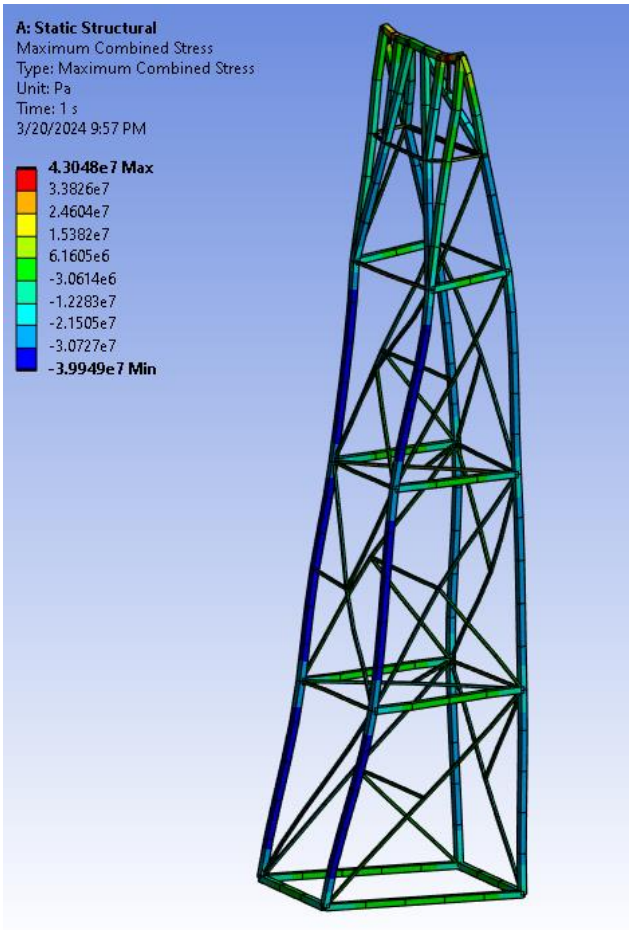



Figure 5. Max Combined Stress

From figure above, the absolute maximum value of the minimum combined stress is 41.369 MPa, and the absolute maximum value of the maximum combined stress is 43.05 MPa, and the factor of safety is indicated as below:

$$FS_{stress} = \min_{\substack{For\ all\ beam \\ elements}} \left\{ \frac{S_y}{|Min\ \ Combined\ \ Stress|}, \frac{S_y}{|Max\ \ Combined\ \ Stress|} \right\}$$

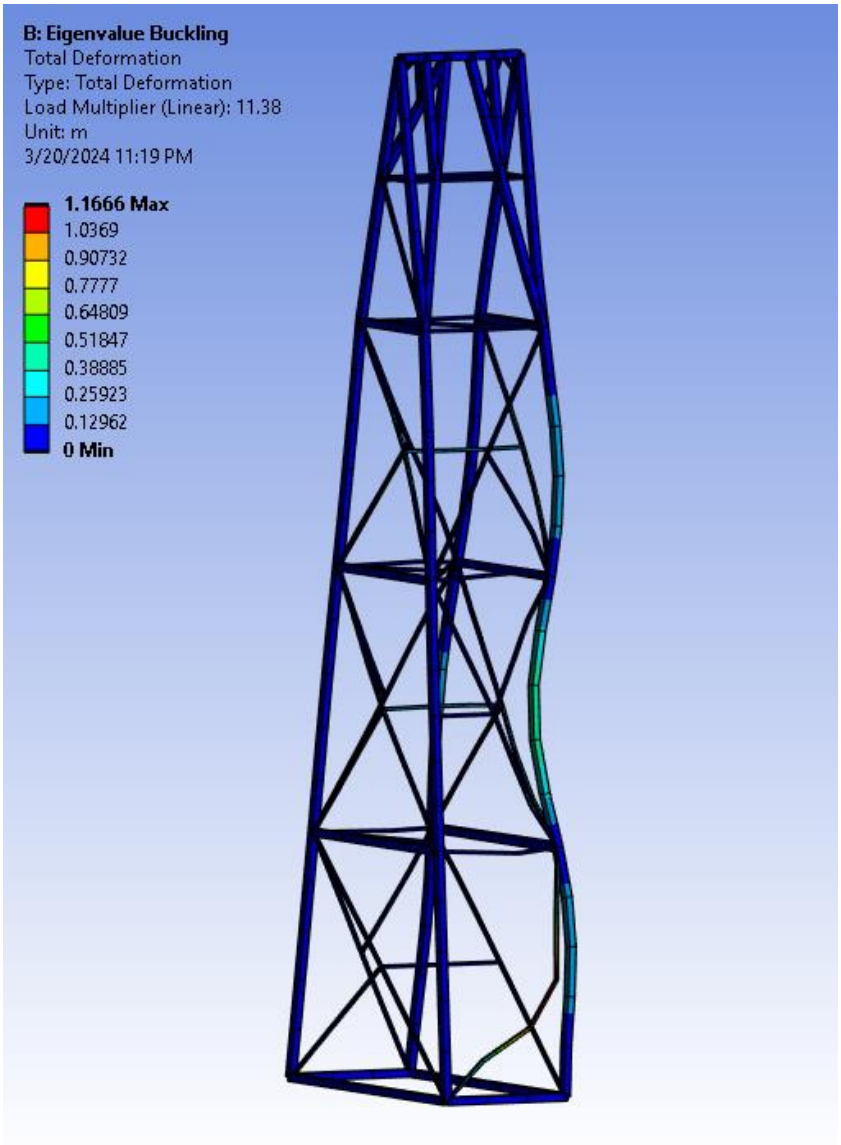
$$FS_{stress} = \min\ (S_y / 41.369, S_y / 43.05)$$

$$FS_{stress} = \min\ (6.043, 5.807)$$

$$\mathbf{FS_{stress} = 5.807}$$

So the final factor of safety is **5.087**, which is larger than the required safety factor of 5.

For eigenvalue buckling, the Load Multiplier is 11.38, so the $\mathbf{FS_{Buckling}}$ **= 11.38**




## Conclusion

In this assignment, we explored the trade-off between structure design and construction material usage, with an optimization criterion of maximum the factor of safety while maintaining a low structure weight (less than 3600 kg). As a result, the final structure of the tower can be designed and simulated under the fulfillment of all design criteria. A further development direction could be using non-constant cross-section, which will further reduce the structure weight while maintaining same factor of safety.