# ANALYSIS OF ROOF TRUSS

Project 1

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## Contents

## Abstract

In this project, a 3D roof truss was analyzed using finite element analysis to see how it would hold up under the weight of roofing materials and snow. A uniform load of 150 $lbf/ft^2$ was applied across the sloped roof surface and was assumed to be distributed among 8 truss assemblies to simulate realistic conditions. The model used truss elements and was initially supported only at the two ends of the bottom chord.

With just the end supports, the truss showed a maximum deflection of 3.13 inches at the center, which seemed too high to be acceptable. When a vertical support was added at the center of the bottom chord, the deflection dropped significantly to 0.75 inches. Based on this, adding a central support is recommended to keep the structure stable and prevent excessive sagging.

## Introduction

In this analysis, a 2D truss structure was modeled to simulate load conditions on one of the trusses of a 40 ft × 80 ft roof. The purpose of this FEA model is to analyze the roof truss structure to determine the deflection of the truss against the combined load of roofing materials and snow, and if additional supports are required on the truss structure to reduce the displacement.

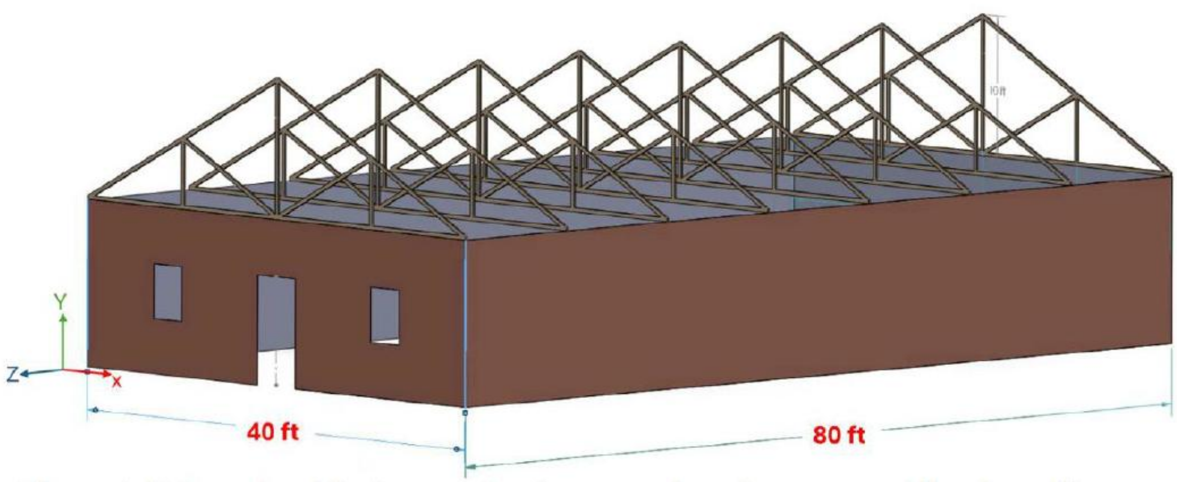



***Figure 1: Schematic of the house, showing several roof truss assemblies***

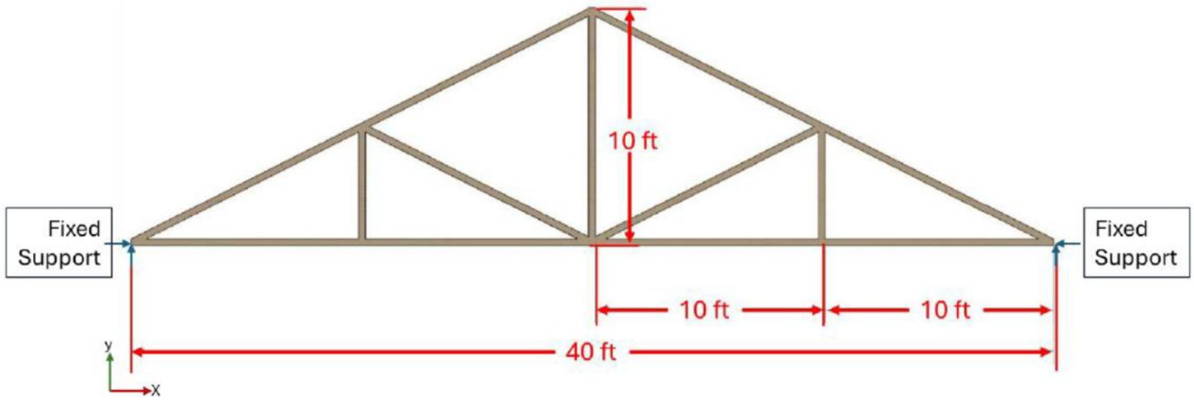



***Figure 2: 2D drawing of a single roof truss assembly showing dimensions and initial fixed boundary conditions***

Each truss member in the structure uses standard construction Western White Pine wood with cross-sectional dimensions of B x H = 3.5 in. x 1.5 in. = 5.25 in$^2$ as shown in Fig 3.

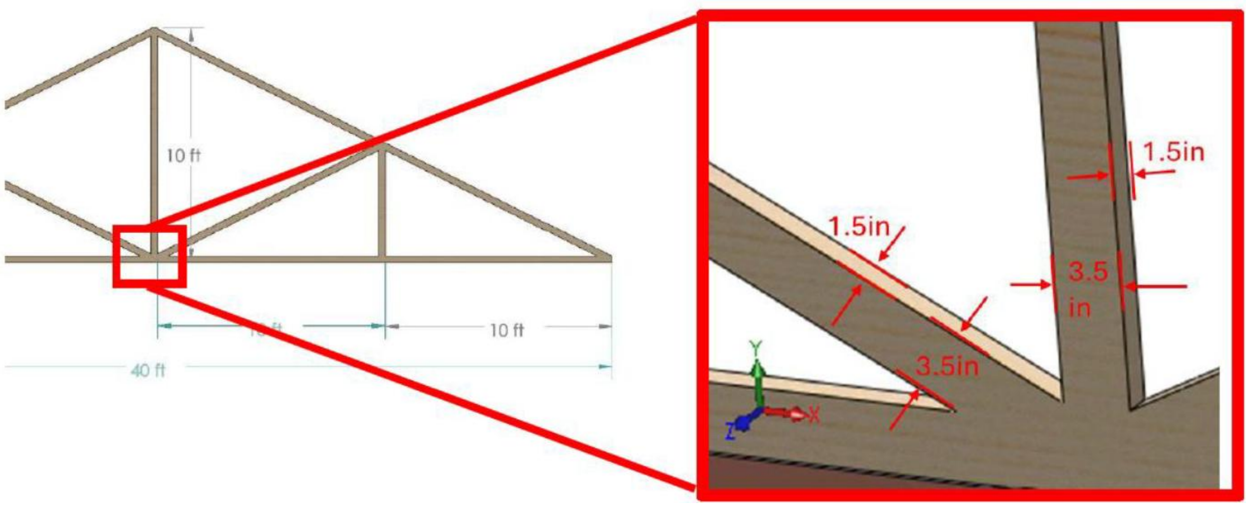



***Figure 3: Close-up of a roof truss member showing the dimensions and orientations***

## Analysis Procedure

The 2D truss structure (figure 4) was modeled in ANSYS's design modeler with the given 2D dimensions (figure 2) with a rectangular cross section (figure 5).

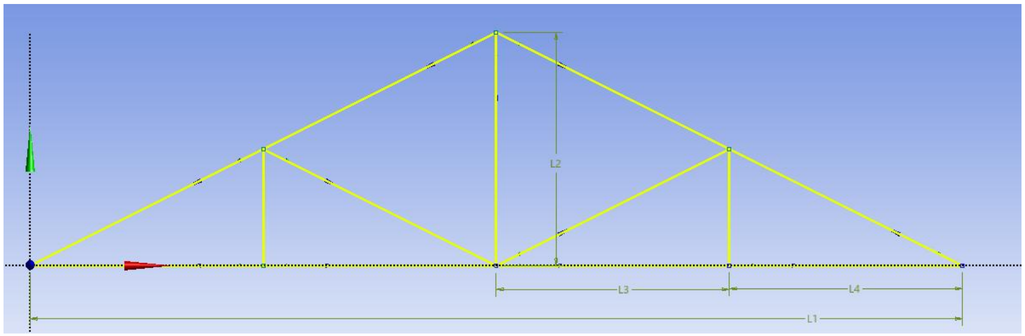



***Figure 4: 2D Truss model with links***

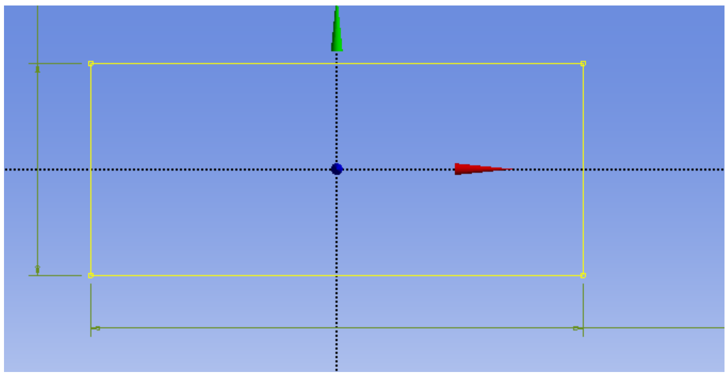


***Figure 5: Cross section of the truss member with B = 0.29 ft , H = 0.125 ft***

The model is imported into ANSYS mechanical and the following properties applied:

**Analysis type**: 3D

**Material Properties**: Western White Pine wood (E = 10 GPa, *v* = 0.3), with isotropic behavior.

**Element type**: Truss elements

**Mesh**: Edge sizing defined so that only one element is between two nodes, because it will be impossible to achieve equilibrium at intermediate nodes if there are multiple elements.

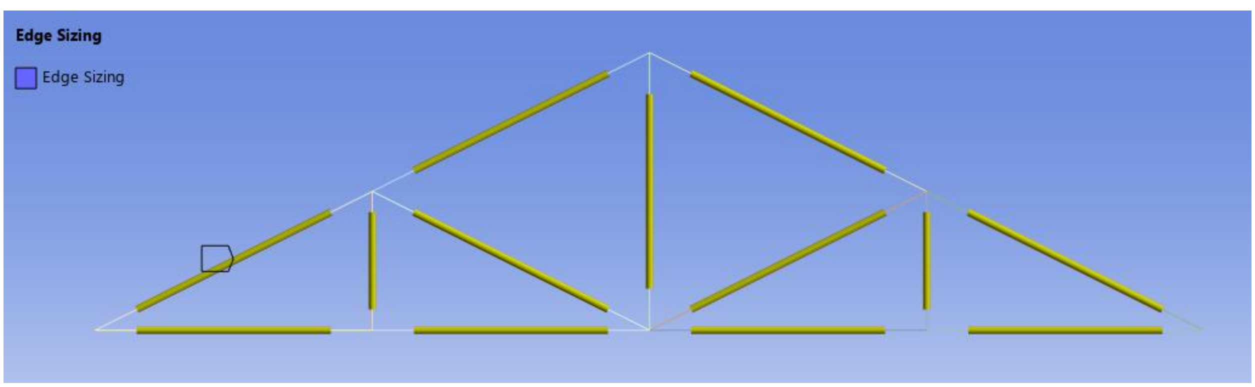



***Figure 6: Meshed model***

Number of elements: 13

Number of nodes: 21

## Load calculation

**Assumptions**:

- The given total combined load of roofing materials and snow of 150 lbf/ft$^2$ acts normal to the slant surface of the roof.
- No of trusses = 8 (inferred from picture in the problem statement)

Refer Appendix for hand calculations.

Total sloped area: 3,577.6 ft$^2$

Total Load: 536,656 lbf.

Load per truss: 67,082 lbf.

Load per top chord (half truss) resolved into components:

- Fx = 30,000 lbf
- Fy = -15,000 lbf

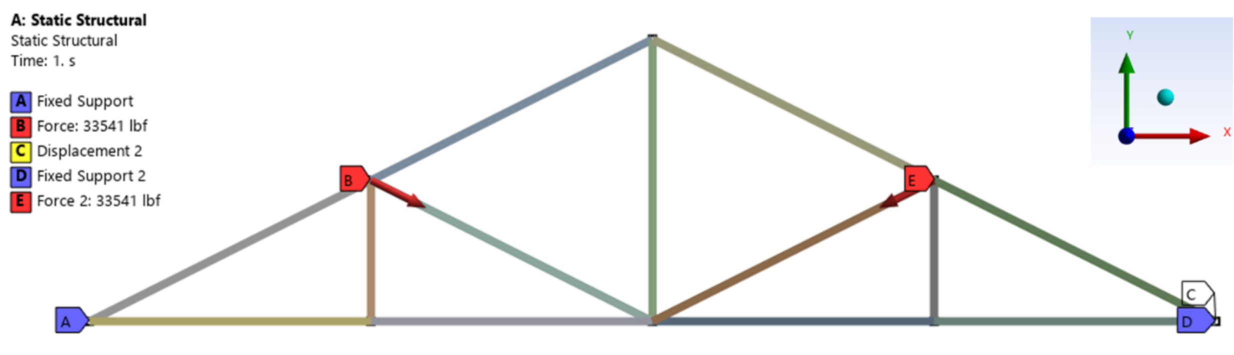



***Figure 7: Boundary conditions - config 1***

## Boundary conditions – Configuration 1

- Fixed support at Node A & Node D
- Displacement of all nodes constrained in z-direction since we haven't defined a 3D shape. Solver fails without this constraint.
- Forces applied at:
    - Node B: Fx = 30000 lbf; Fy = -15,000 lbf
    - Node E: Fx = -30000 lbf; Fy = -15,000 lbf

## Boundary conditions – Configuration 2

In addition to the boundary conditions in config 1, we add another fixed support at the center of the bottom chord.

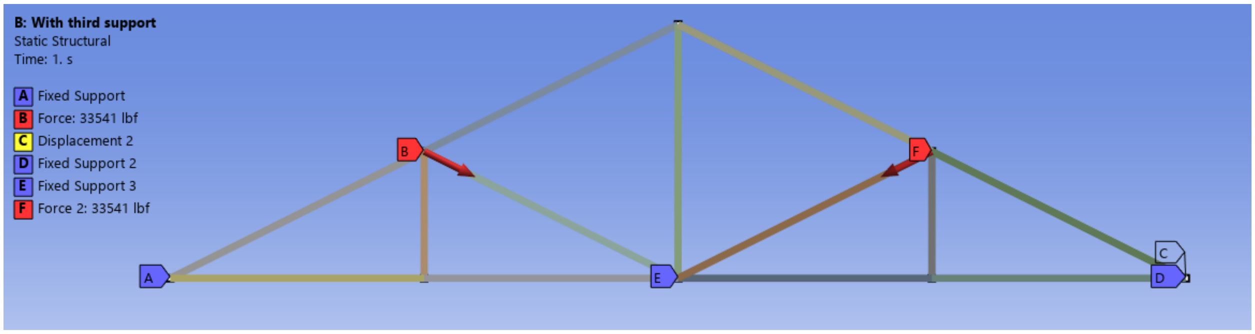



***Figure 8: Boundary conditions - config 2***

# Results

## Configuration 1

1) **Total Deformation of the truss**

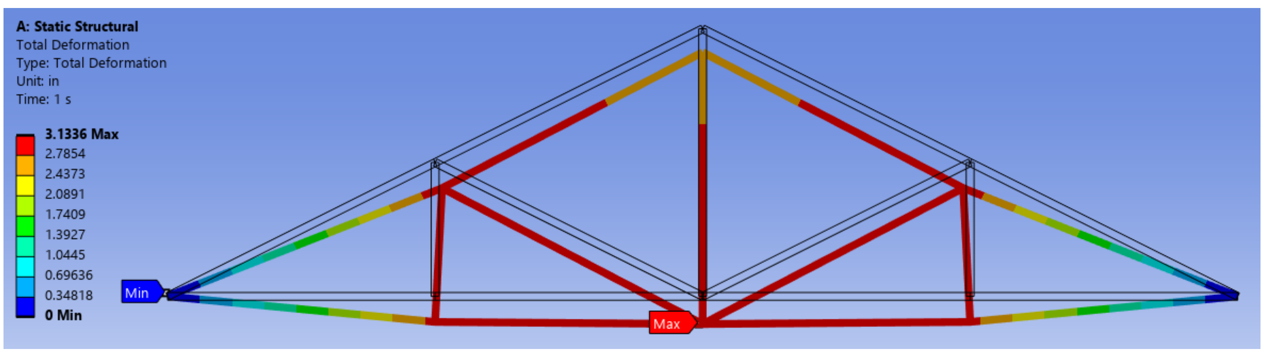



***Figure 9a: Total deformation (shown on 4x scale) of truss assembly under combined roof and snow load.***

A maximum deflection of **3.13 inches** was observed at the center of the truss.

2) **Directional deformation in x-direction**

A maximum deflection of **0.78 inches** was observed at the top chord's load application points in the x - direction.

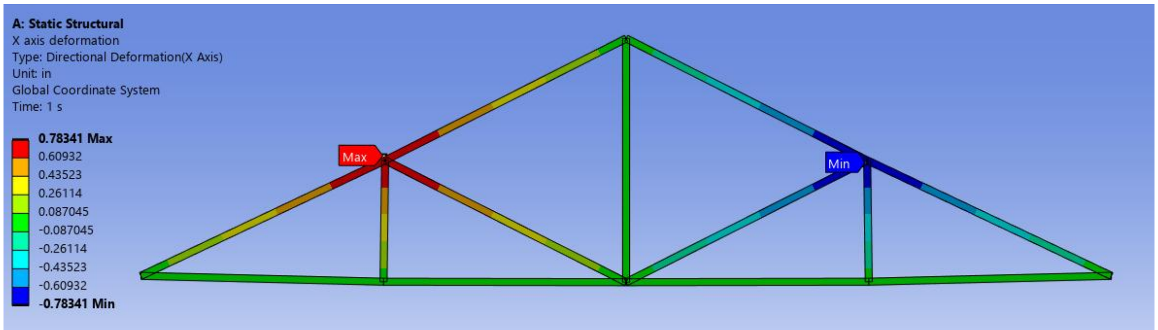



***Figure 9b: X - axis deformation (shown on true scale)***

### 3) Directional deformation in y-direction

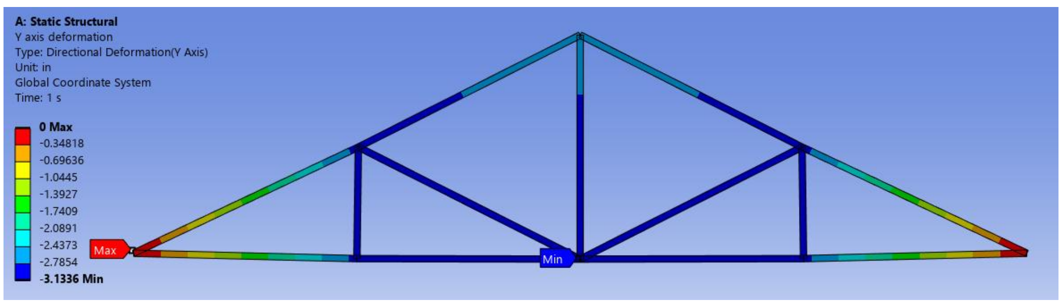



***Figure 9c: Y - axis deformation (shown on true scale)***

A maximum deflection of 3.13 inches downwards observed at the center of the bottom chord.

## Configuration 2

### 1) Total Deformation of the truss

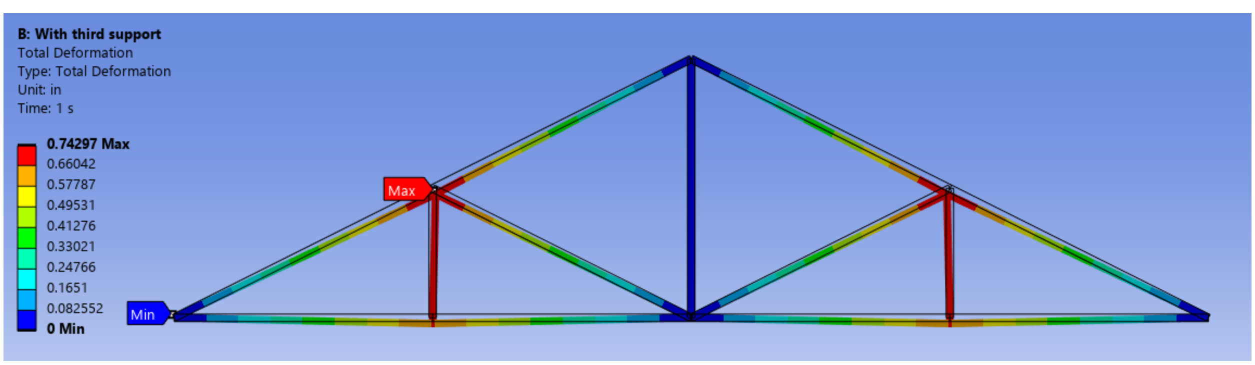



***Figure 10a: Total deformation (shown on 4x scale) of truss assembly under combined roof and snow load.***

A maximum deformation of **0.74 inches** is observed at the top chord where load was applied.

2) **Directional deformation in x-direction**

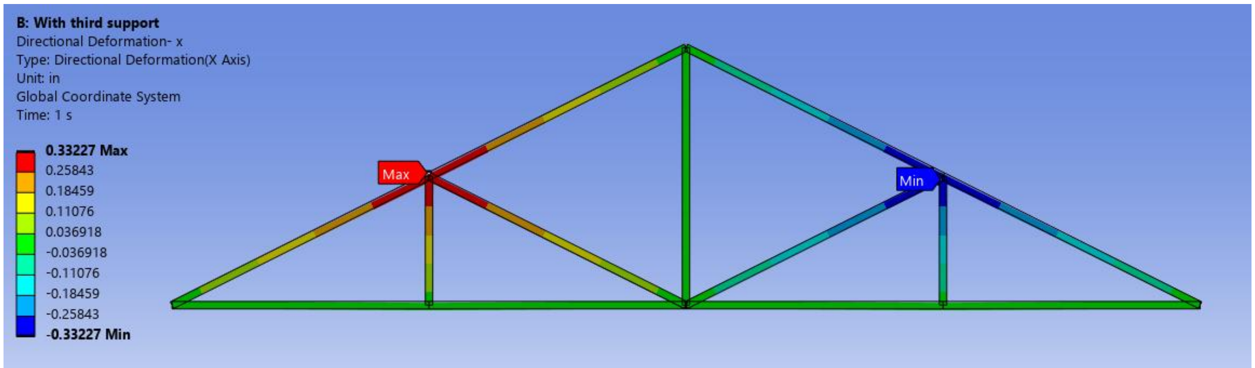



***Figure 10b: X- axis deformation (shown on true scale)***

A maximum deflection of **0.33 inches** observed at the top chord's load application points in the x - direction.

3) **Directional deformation in y-direction**

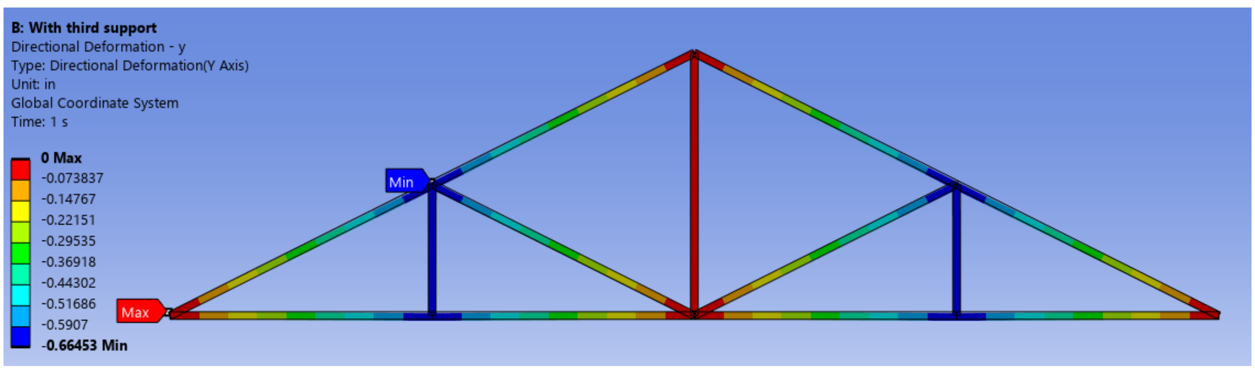



***Figure 10c: Y - axis deformation (shown on true scale)***

A maximum deflection of **0.66 inches** downwards was observed at the center of the bottom chord in the y – direction.

## Discussion

The simulation results indicate that the original support configuration—with fixed supports only at the two ends of the bottom chord—results in a maximum deflection of 3.13 inches at the center of the roof truss. For a typical roof structure, such a magnitude of vertical displacement may lead to structural instability or long-term performance issues, such as sagging or stress concentration in roof panels.

To evaluate whether additional support is necessary, a second simulation was performed with an added vertical support at the center bottom node of the truss (mid-span). In this case, the maximum deflection reduced to approximately 0.75 inches, a 76% reduction, indicating significantly improved structural performance.

This suggests that the initial support condition is not adequate for the expected roof and snow loads. The large deflection can be attributed to insufficient vertical restraint in the middle of the span, allowing the structure to flex downward under load.

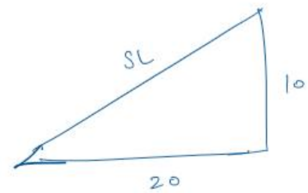
## Conclusions

This analysis evaluated the performance of a 3D roof truss assembly under combined roofing and snow loads using finite element analysis. The initial model, supported only at the two ends, exhibited a maximum vertical deflection of **3.13 inches** at the center of the roof, indicating insufficient support for the applied load.

To address this, a second simulation introduced an additional vertical support at the **mid-span of the bottom chord**, which reduced the deflection to **0.75 inches**, a substantial improvement in structural performance. Based on this result, it is recommended to include a **central vertical support** in the final roof truss design to ensure acceptable deflection limits and improve load distribution.

This added support will enhance the long-term structural integrity of the roof without significantly increasing complexity or material usage.

## Appendix A – Hand Calculations




Slant height $= \sqrt{20^2 + 10^2} = 10\sqrt{5}$

Total Slant area $= 10\sqrt{5} \times 80 \times 2$
(Both Sides of Roof) $= 1600\sqrt{5}\ ft^2$

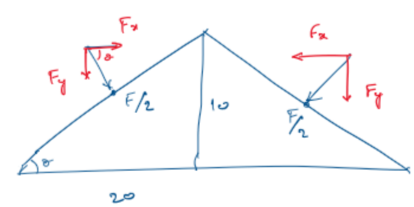
Total load on Trusses $= 150\ lbf/ft^2 \times 1600 \times \sqrt{5}\ ft^2$
$= 24\sqrt{5} \times 10^4\ lbf$

Assuming no of trusses = 8 (from picture)

Load F on each truss $= \dfrac{24\sqrt{5} \times 10^4}{8} = 3\sqrt{5} \times 10^4$

F is normal to the roof.

$\Rightarrow$ Resolve to $F_x$, $F_y$.




$$F_x = \frac{F}{2}\cos\theta = \frac{F}{2} \times \frac{20}{10\sqrt{5}} = \frac{3\cancel{\sqrt{5}}}{2} \times \frac{2\cancel{0}}{1\cancel{0}\cancel{\sqrt{5}}} \times 10^4$$

$$\boxed{F_x = 3 \times 10^4\ lbft.}$$

$$F_y = \frac{F}{2}\sin\theta = \frac{F}{2} \times \frac{10}{10\sqrt{5}} = \frac{3\sqrt{5}}{2} \times \frac{1}{\sqrt{5}} \times 10^4$$

$$\boxed{F_y = 1.5 \times 10^4\ lbft.}$$