Slippery Rock University

Multi-Material Residential Structure

CIVIL 310

M.C
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Executive Summary

A two-story simple residential structure is wanted in Southern Pennsylvania. This structure must be able to withstand the proper dead, live, wind, and snow loads for the indicated area. For proper market placement of a single-family home, the structure will have at least two bedrooms and two bathrooms and have a livable space of at least 1,500 square feet. Through proper column placement and material choice, a cost-effective plan will be developed. After the support structure is completed, a contracting team with continue to work on the walls, electric, plumbing, and other finishing details to complete the single-family home and sell the site for a maximum profit.

Structural Design

Floor Plan

The first step to executing the structure is creating a floor plan. The 2D floor plan for the residential structure was made using the AutoCAD Software and can be seen below in *Figure 1.* There are two floors of the structure which contain 2 bedrooms and 2.5 bathrooms collectively. Each floor of the structure totals 924.4 square feet, indicating the total livable space of the structure is 1848.9 square feet.

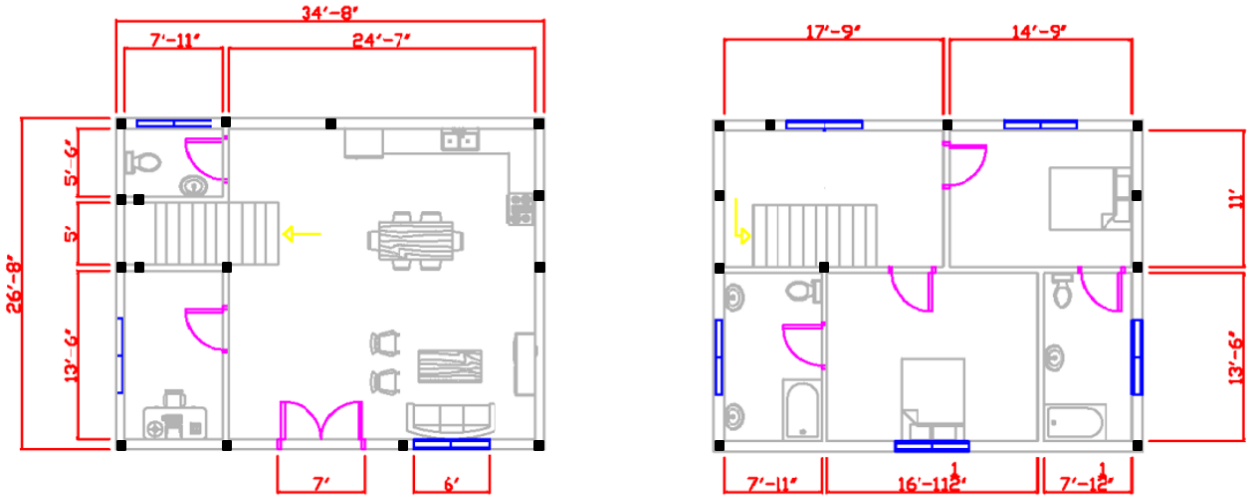

Figure 1 - AutoCAD 2D Floor Plan

3D Rendering

The next step in execution is rendering the 2D floor plan into a 3D structure. The 3D structure, seen in *Figure 2*, was created using the RISA 3D Software. The choice of member placement and materials will be discussed in the following pages.

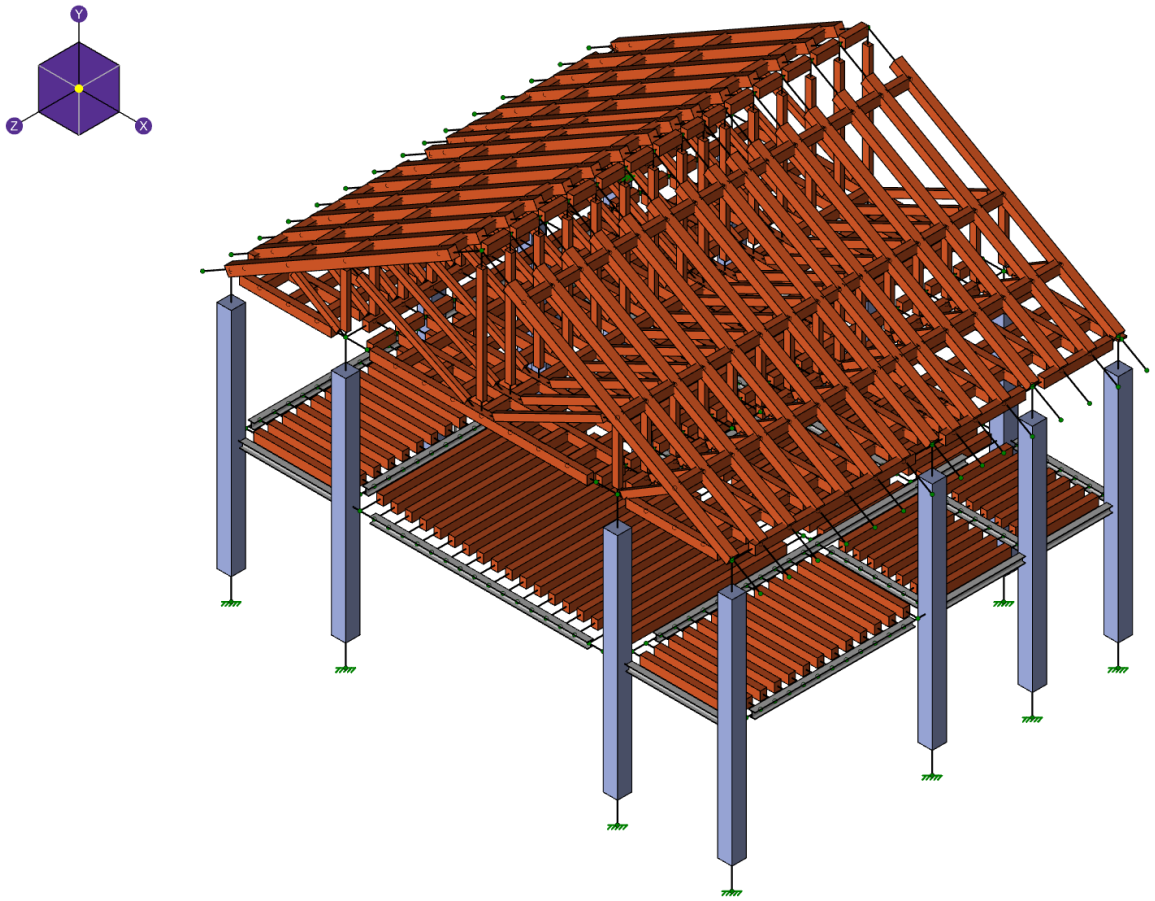

Figure 2 - RISA 3D Structure Rendered, ISO View

Columns

Placement

The placement of the columns was determined by the interior rooms. A column was placed at each corner of the structure and surrounding the stairs. The remaining columns were placed on long spans of exterior walls to relieve part of the load from the main support column located at the corners. Two concrete columns were also placed at the end of the two steel beams accommodating the open concept main floor.

Materials

The support columns for this structure were made from steel and concrete. The concrete support columns were made of Rectangular 4000 psi Normal Weight Concrete with a cross sectional area of 12x12 inches. All exterior concrete columns were 20 feet in height, and the single interior concrete column was 10 feet in height. Two steel columns with a height of 10 feet were added below to stairs to relieve some of the load from the concrete columns placed on the exterior wall of the stairs. The steel columns were Wide Flange A992 Steel with a cross sectional area of 6x8.5 inches.

Loads

There are not exterior loads applied directly to the columns, but each load upon a structure is transferred to the support columns then to the foundation. Each support column has a fixed boundary condition with the foundation and is pinned on the other side with either a steel girder, wooden beam, or a wooden roof truss. The boundary conditions of the support columns can be seen below in *Figure 3*. The concrete support columns are represented by the orange members, and the steel support columns are represented by the green members.

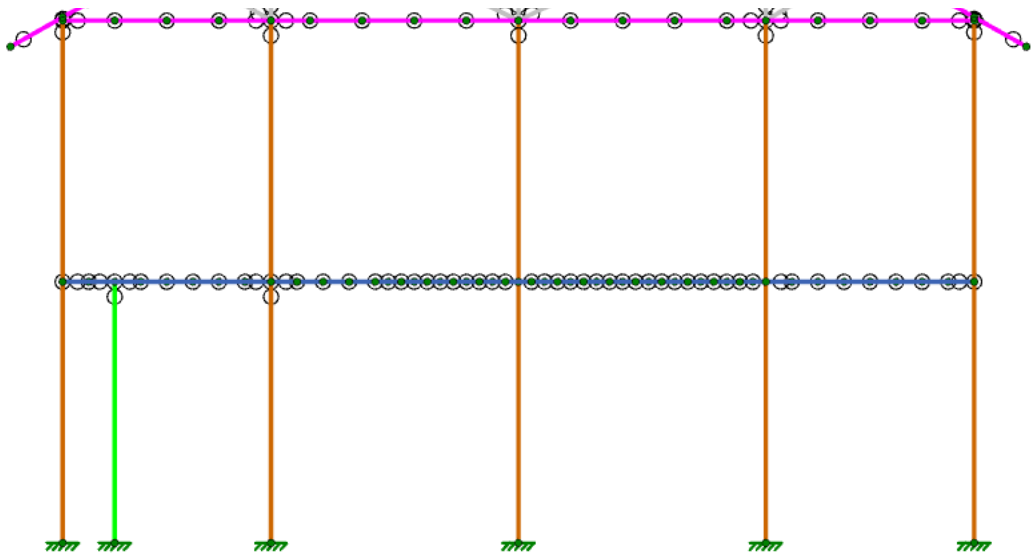

Figure 3 - Column Boundary Conditions, XY View

Member Analysis

The interior single story concrete column was chosen for member analysis in RISA 3D. *Figure 4* shows the external forces on the specific member due to the boundary conditions applied. Determining the exterior forces on the column helps to determine the appropriate diagrams for the member. The column is fixed on the left side and pinned on the right side. The fixed side of the column has a force in both the x and y direction and a moment. The pinned side of the column has a force in the x and y direction but does not have a moment. This indicates the x and y forces are equal but opposite because the column doesn't have any other external forces. This can be demonstrated in the diagram analysis shown in *Figure 5*. *Figure 6* below shows that the concrete column passes all structural limits.

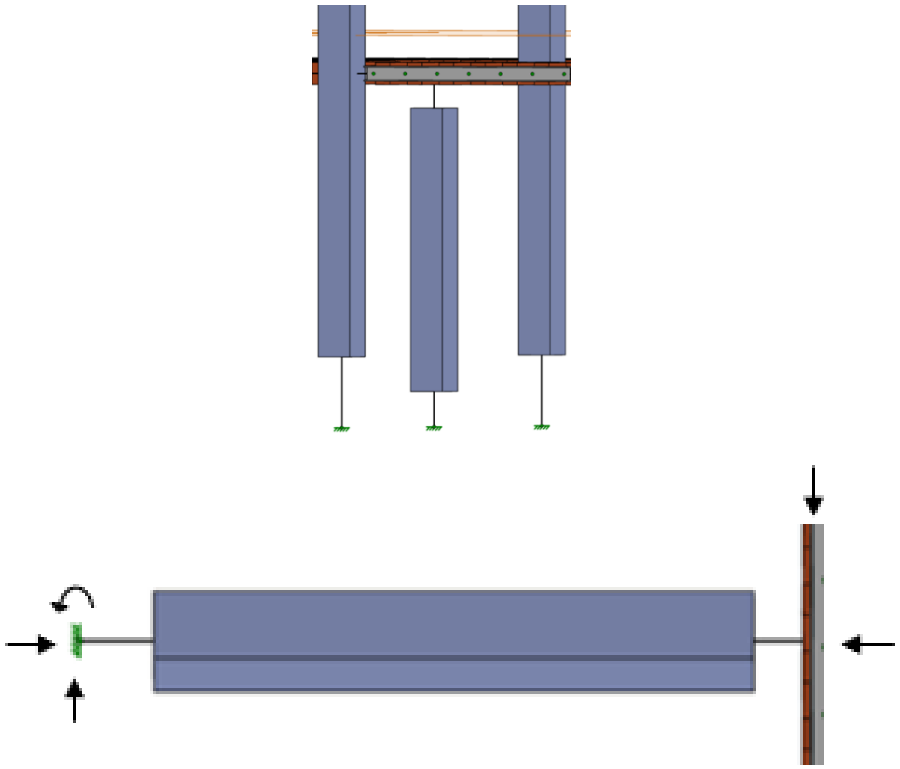

Figure 4 - Concrete Column Analysis

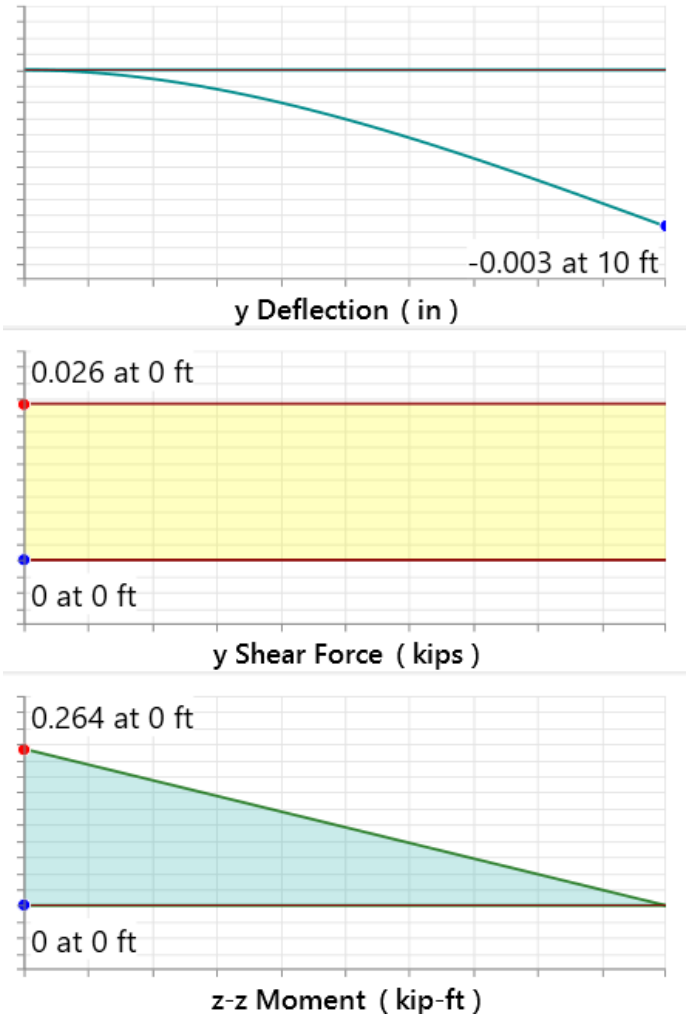

Figure 5 - RISA Column Analysis Diagrams

Limit State	Gov. LC	Required	Available	Unity Check	Result
Applied Loading - Bending/Axial					
Flexural Reinforcement	1	1.44 in^2	1.767 in^2	-	Pass
Axial Capacity		0.000 k	383.253 k	-	-
Bending Unity Check	1	-	-	0.026	Pass
Y Shear Design Strength	0	0.032 k	25.454 k	0.001	Pass
Z Shear Design Strength	0	0.377 k	25.454 k	0.015	Pass
Threshold Torsion		0.000 k-ft	1.781 k-ft	1	Pass
Span Information					
Rebar Detailing					

Figure 6 - Concrete Member Analysis Results

Walls

Placement

To accommodate the open concept floor plan wanted to maximize livable square footage, two large steel beams connect the first and second floors from the stairs to the opposite exterior wall. Steel girders line the second story floor perimeter along with being directly below any interior wall on the second story. Between the steel girders, wooden floor joists were placed no more than 12 inches apart according to ASCE standards.

Materials

The girders were made from A992 Wide Flange Steel with a cross sectional area of 5x19 inches. The wooden beams were Douglas Fire Balanced Glulam with a cross sectional area of 5.5x7.5 inches. Originally, the chosen cross section for the beam was 2x8 inches, but the suggested material of 5.5x7.5 reduced the deflection of the members.

Loads

The walls receive an exterior wind load of 0.01 ksf (kips/ft^2) according to ASCE Standard as seen in *Figure 7* below. Depending on which way the wind is blowing at the time, the windward wall of the structure will change, which is why the wind load was applied as an area load to all sides of the structure.

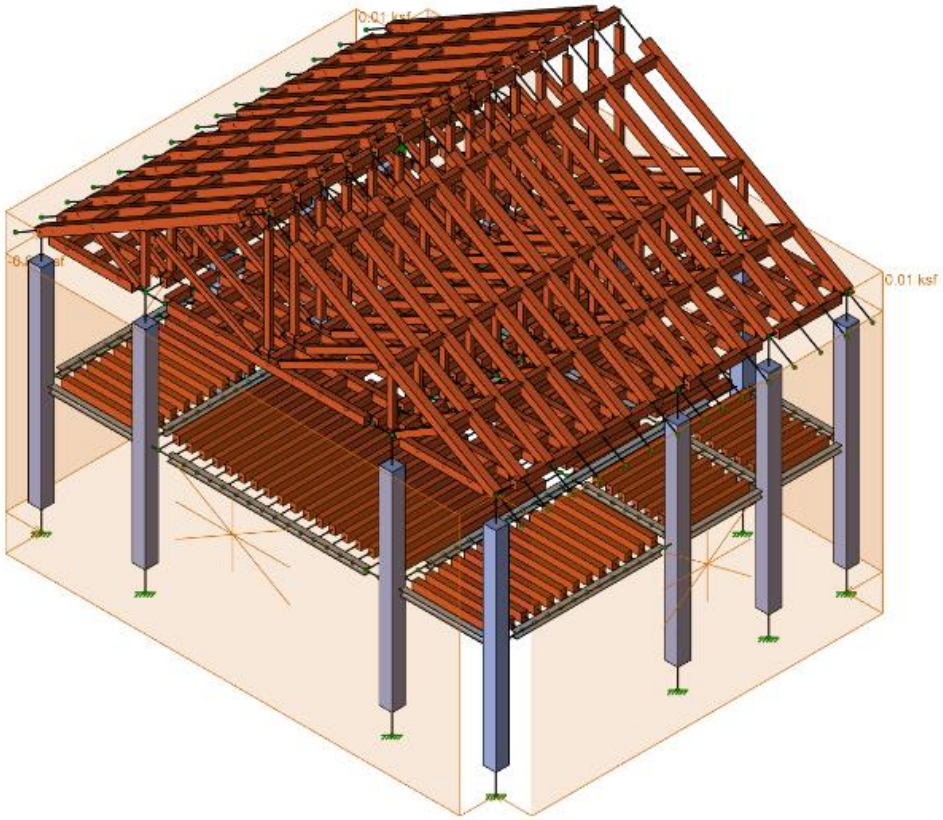

Figure 7 - Wind Loads, ISO View

According to ASCE, a live load of 0.04 ksf is standard for residential buildings. This live load was applied as an area load to the floor of the second story to account for the load of furniture and people that will constantly be transferred to the support columns. The live load can be seen below in *Figure 8.*

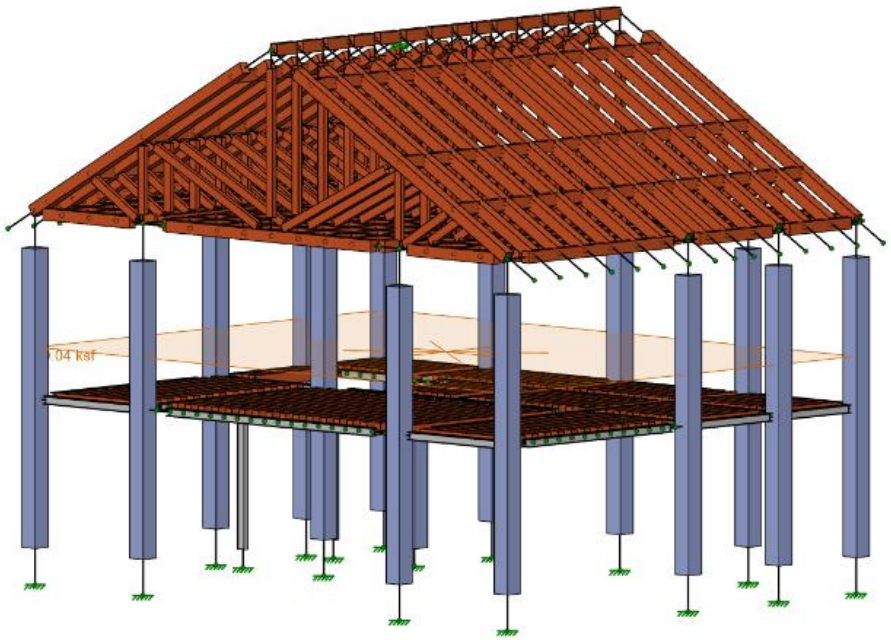

Figure 8 - Live Loads

The steel and wood members creating the floor of the second story have pinned boundary conditions on either side of each member which can be seen below in *Figure 9*. The wooden floor joists are represented by the red members and the steel girders are represented by the dark blue members.

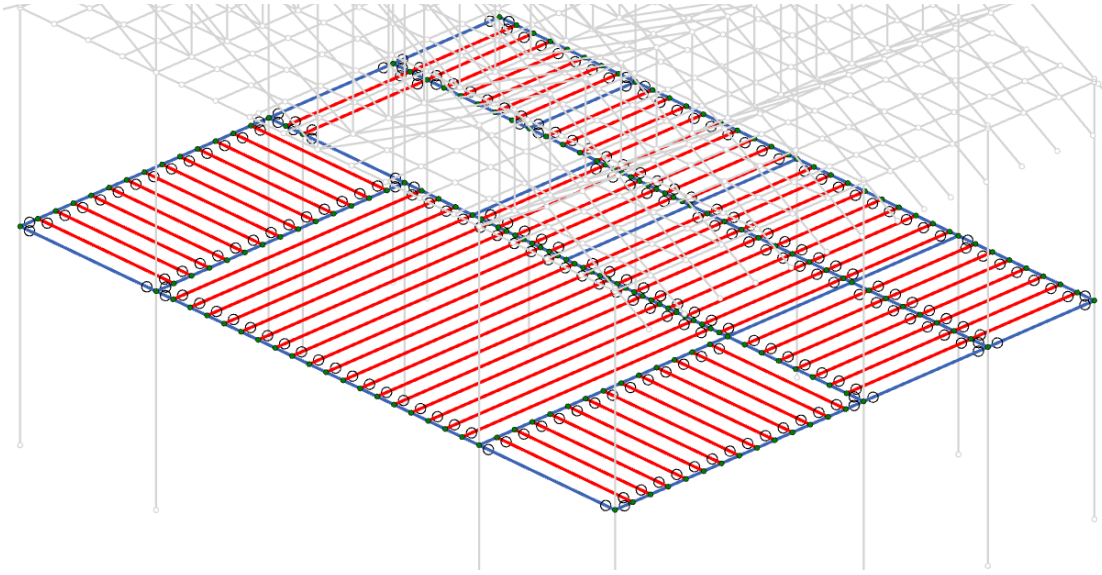

Figure 9 - Second Story Floor Layout, ISO View

Roof

Placement

The placement of each truss was determined by a standard. According to ASCE, residential roof trusses should be no more than 2 feet apart. The span of the truss is 34.67 feet, and the bay is 26.67 feet.

Materials

The entire roof was made from Douglas Fir Balanced Glulam. The chords had a cross-sectional area of 6.75x7.5 inches. The purlins had a cross-sectional area of 5.5x7.5 inches. The bracing had a cross-sectional area of 3.5x5.5 inches. Originally, the cross-sectional area chosen for the purlins was 2x8, but the deflection was very high and the suggested material for better support came to be 5.5x7.5.

Loads

According to ASCE, snow loads of 0.025 ksf to 0.035 ksf are standard for Pennsylvania. The higher standard of 0.035 was chosen for this structure because of the concrete columns supporting the house. The snow loads were applied as line loads to the top chords of each roof truss and can be seen below in *Figure 10*. Each wooden member of the truss, regardless of cross-sectional area, has a pinned boundary condition on either side which can be seen below in *Figure 11* and *Figure 12*. The chords are represented by the pink members, the purlins are represented by the light blue members, and the bracing of the truss is represented by the gray members.

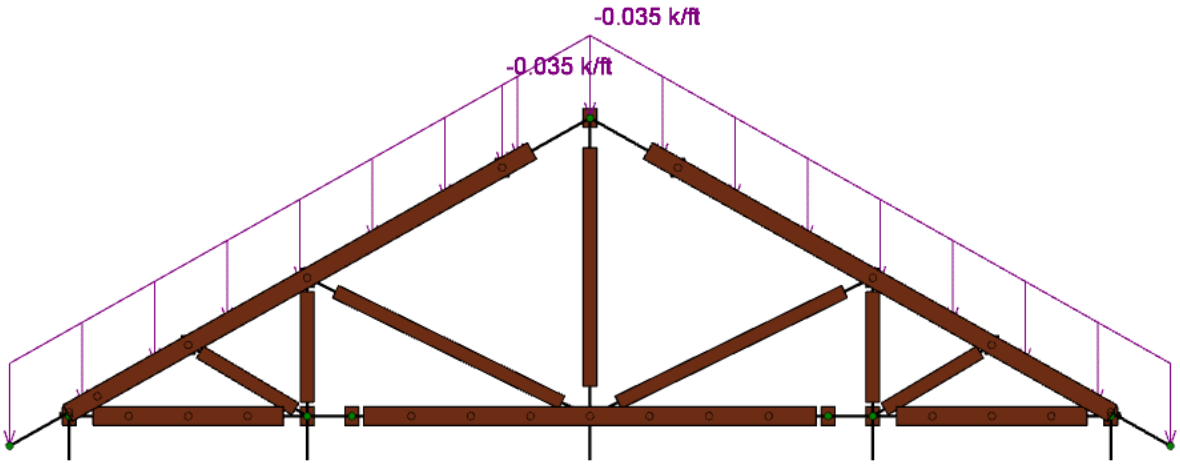

Figure 10 - Snow Loads, XY View

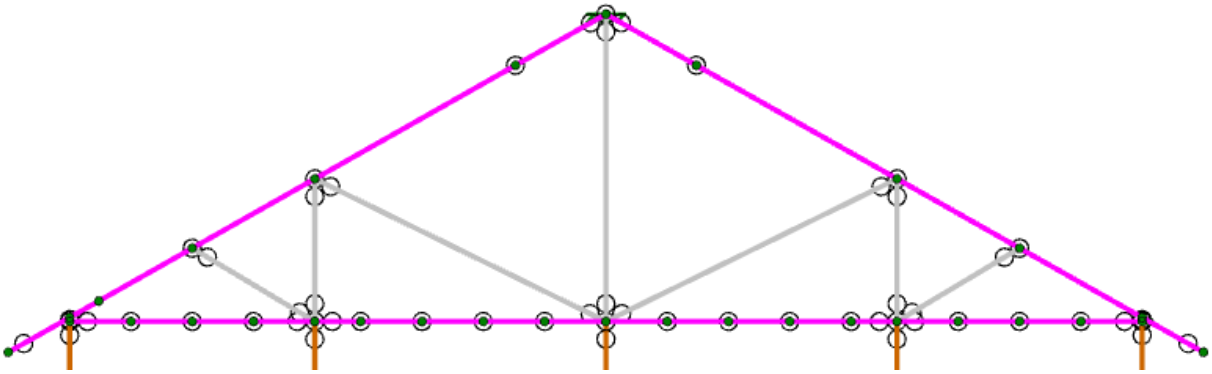

Figure 11 - Roof Truss Boundary Conditions, XY View

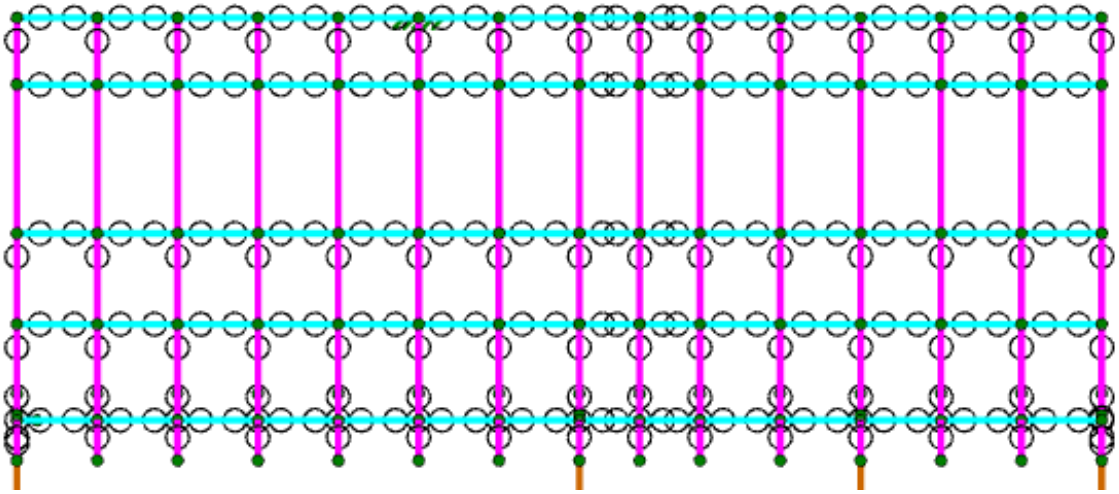

Figure 12 - Roof Truss Boundary Conditions, YZ View

Cost Analysis

The budget spent on each material is broken down in *Figures 13 & 14* below. The standard market prices for the materials were found from sources online including Lowe's website. Hot Rolled Steel is priced at $1.25 per pound, Glulam Doulas Fir Balanced Wood is priced at $0.77 per foot, and Concrete is priced at $117 per cubic yard. More than half of the project cost was spent on the steel girders, which was expected because of the long support beams accommodating the open concept main floor.

Material	Size	Pieces	Length[ft]	Weight[K]
Hot Rolled Steel				
A992	W6X8.5	2	20	0.171
A992	W5X19	26	261	4.938
Total HR Steel		28	281	5.109
Wood				
24F-1.8E DF Balanced	3.5X5.5FS	105	746.1	3.491
24F-1.8E DF Balanced	6.75X7.5FS	35	706.9	8.699
24F-1.8E DF Balanced	5.5X7.5FS	458	2005	20.103
Total Wood		598	3458	32.292
Concrete Members			Volume (yds^3)	
Conc4000NW	CRECT12X12	15	10.8	42.199
Total Concrete		15	10.8	42.199

Figure 13 - Material Takeoff

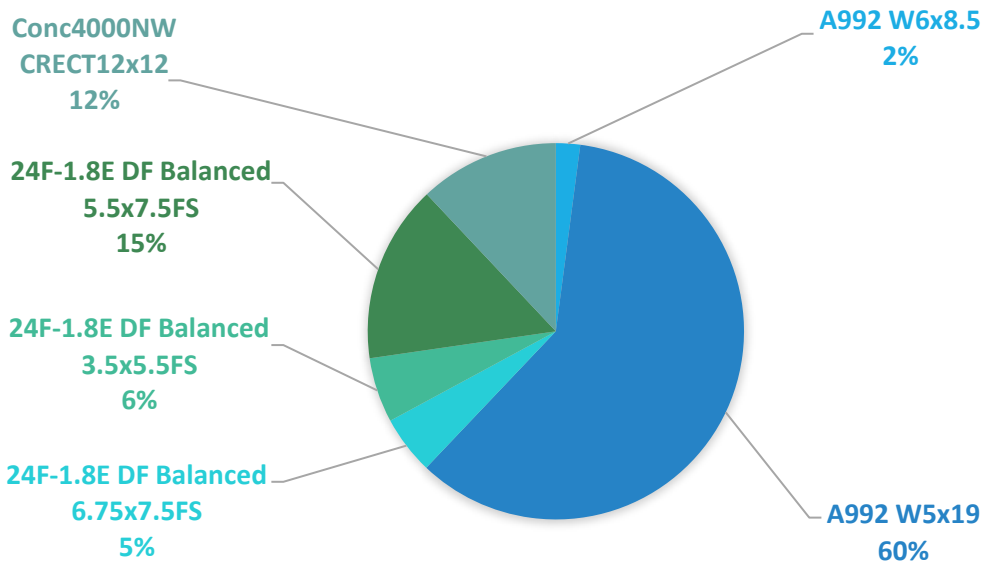

Figure 14 - Cost Analysis

Conclusion

The residential support structure created is passed to contracting teams to frame the interior and exterior walls and complete the project for the housing market. The final design has 2 bedrooms and 2.5 bathrooms, with a total livable area just under 1,850 square feet. The total cost of the two-story multi-material residential simple support structure came to $10,312.51 with the suggested materials chosen to withstand the ASCE Standard loads. Overall, the structure was able to be built with the market parameters and structural limits.