Structural Engineering

CIVL 310

Prepared For:

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Abstract

This report will discuss multiple aspects of my structure design. The structure needed to have multiple materials including wood, steel, and concrete. The design resulted in a structure known as a pole barn which had several unique aspects during the design process. The first aspect that will be discussed is the inspiration as well as the overall design process for the structure. Afterward, there will be structural analysis on each unique member to make sure the building is structurally sound. The final aspect will be the cost analysis regarding the members used in the design as well as other aspects involving utilities and labor.

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Inspiration

The inspiration for this design is a relatively versatile building known as a pole barn. This building is relatively large and can serve multiple purposes with the two main functions being a storage building, such as a garage, and a public gathering area, such as a pavilion. This pole barn was designed with the purpose of acting as a car garage. The building typically contains a concrete floor with multiple columns connecting to the floor. These columns are typically only on the longer side of the concrete floor. There are trusses that are placed on top of each of these columns going across the short side of the structure. The last defining feature is the purlins which span across the top of the trusses and support the roof.

Floor Plan

The first step of the design process for this pole barn is to create a floor plan. By using the generic outline listed in the prior section, the floor plan shown in Figure 1 was created. Figure 1 shows two different floor plans. The leftmost outline is the generic outline showing the cover outline with dimensions of 12’ x 24.5’. The rightmost outline is a similar plan but also shows the column layout for the pole barn. The columns are highlighted in yellow and there are a total of five columns on each long side. These columns are spaced 6’ apart when measuring from the same point on both columns. The columns themselves have dimensions of 6” x 6”.

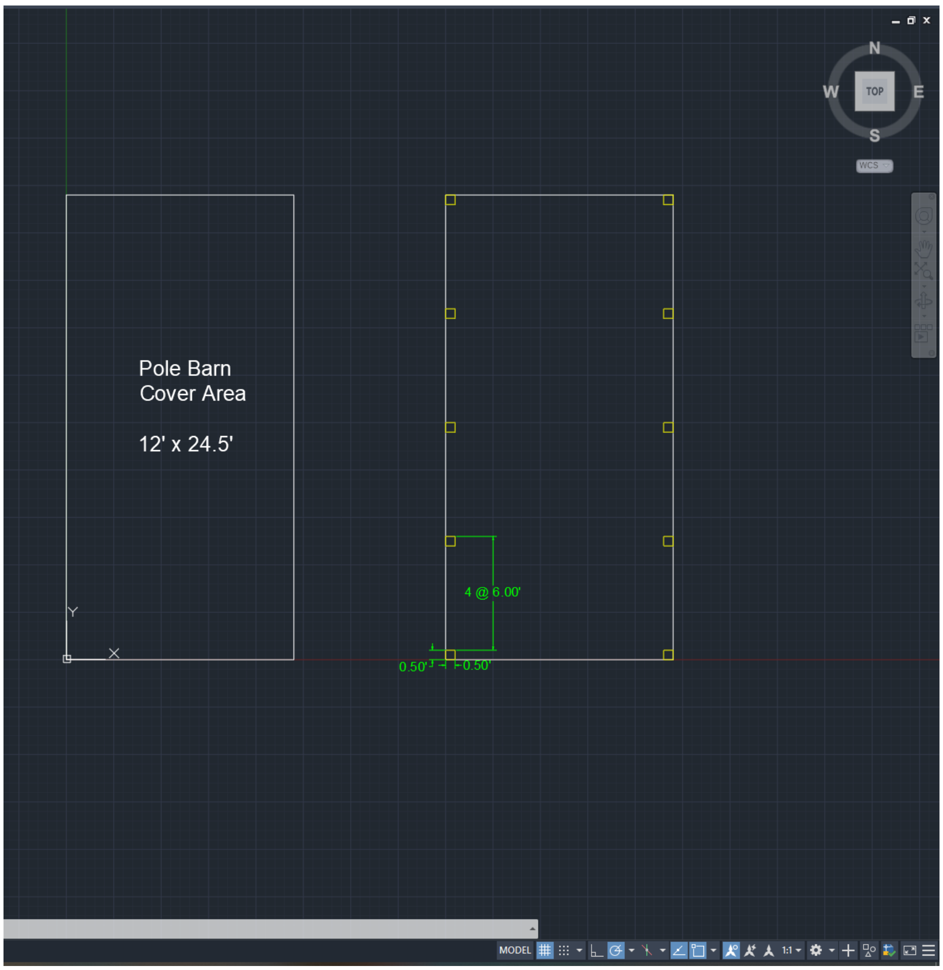

Figure 1. The floor plan for the pole barn

3D Rendering

The 3D rendering process began by deciding which materials to use for different members of the house. After careful consideration, the following materials were picked to be used in the design.

- Douglas Fir Wood for the columns supporting the roof and the purlins going across the trusses.
- A36 Grade 36 Hot Rolled Steel for the truss members.
- 3000NW Concrete for the floor slab and supporting concrete members.

These materials were picked for both their price effectiveness and their ability to satisfy the project conditions. Notable features of the 3D rendering not specified in the floor include the wooden columns being 8 feet high and the concrete columns going 8 feet down into the ground. The concrete foundation has a thickness of 6 inches and the trusses go 6 feet above the columns to support the roof. Shown below is Figure 2 which is the 3D model of the pole barn once rendered in 3D.

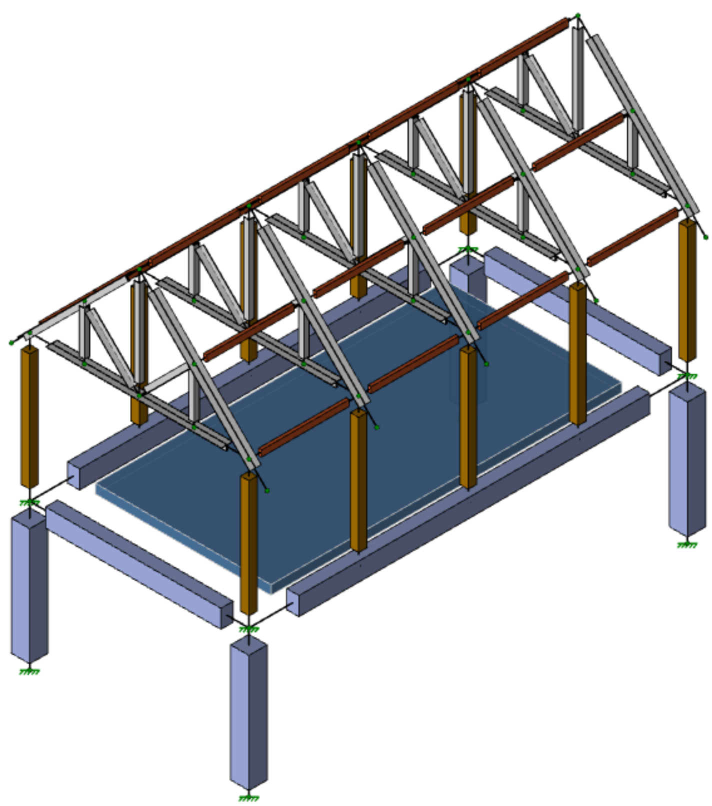

Figure 2. The 3D rendering of the skeleton of the pole barn

The only aspect of the design not visible in Figure 2 are the loads applied on the pole barn. There are four types of loads which are all applied to the pole barn in several different. The first load type is the dead load which is just the self-weight of the structure. The second load type is the live load which is applied in two different places. The first place is on the purlins which receive a live load of 0.1 k/ft going downward. The second place is on the concrete slab which receives a live load of 0.04 k/ft^2 going downward. The third load type is the wind load which is applied to the five leftmost columns with a magnitude of 0.05 k/ft going to the right. The final load type is the snow load applied on the purlins. The middle three lines of purlins receive a snow load of 0.1 k/ft downward while the outer two purlin lines only received a snow load of 0.05 k/ft downward.

Structural Analysis

When looking at the unique beams used for this project, they can be identified as five unique beams in terms of structural analysis. The first of these five are the concrete beams seen at the bottom of Figure 2. The concrete beam had no deflection and only withstood a vertical force which is to be expected based on the location of the beam. This information is summed up in Figure 3 below.

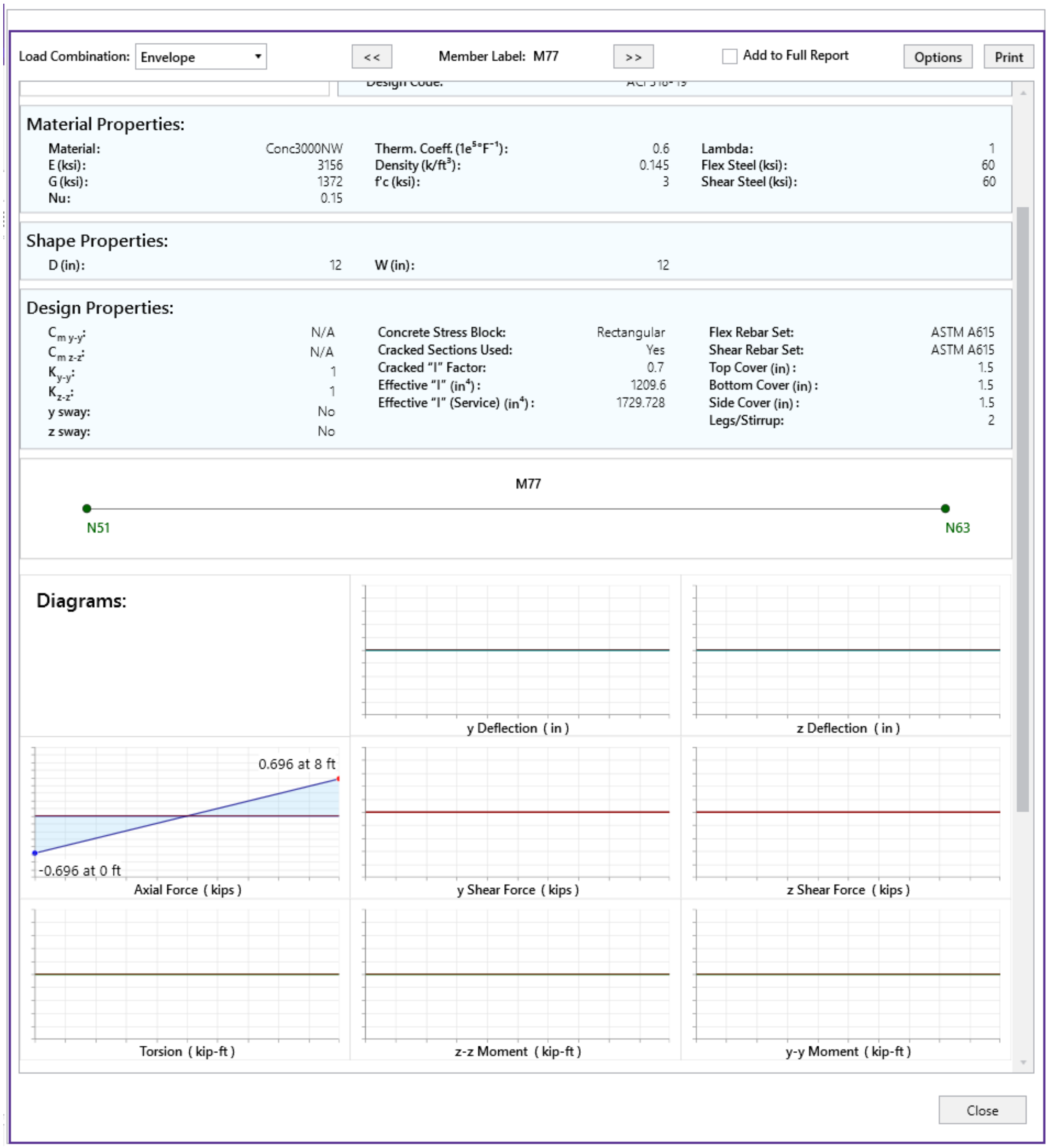

Figure 3. Structure report of one of the concrete columns

The second of the five unique beams for this project are the concrete beams that outline the foundation. There are two versions of these beams depending on their location. The beams on the side with the five wood columns will have varying properties due to the five columns connected to them. This is reflected in Figure 4 which shows the structural report for this kind of beam. It should be noted that the deflection, shear, and moment all have sharp increases shortly before each column and sharp decreases after the location after each column. For the other type of concrete beam, with no wooden columns except at the endpoints, the quantities for deflection, shear, and moment will be far more consistent as there are no wooden columns on the middle of the beam impacting the properties.

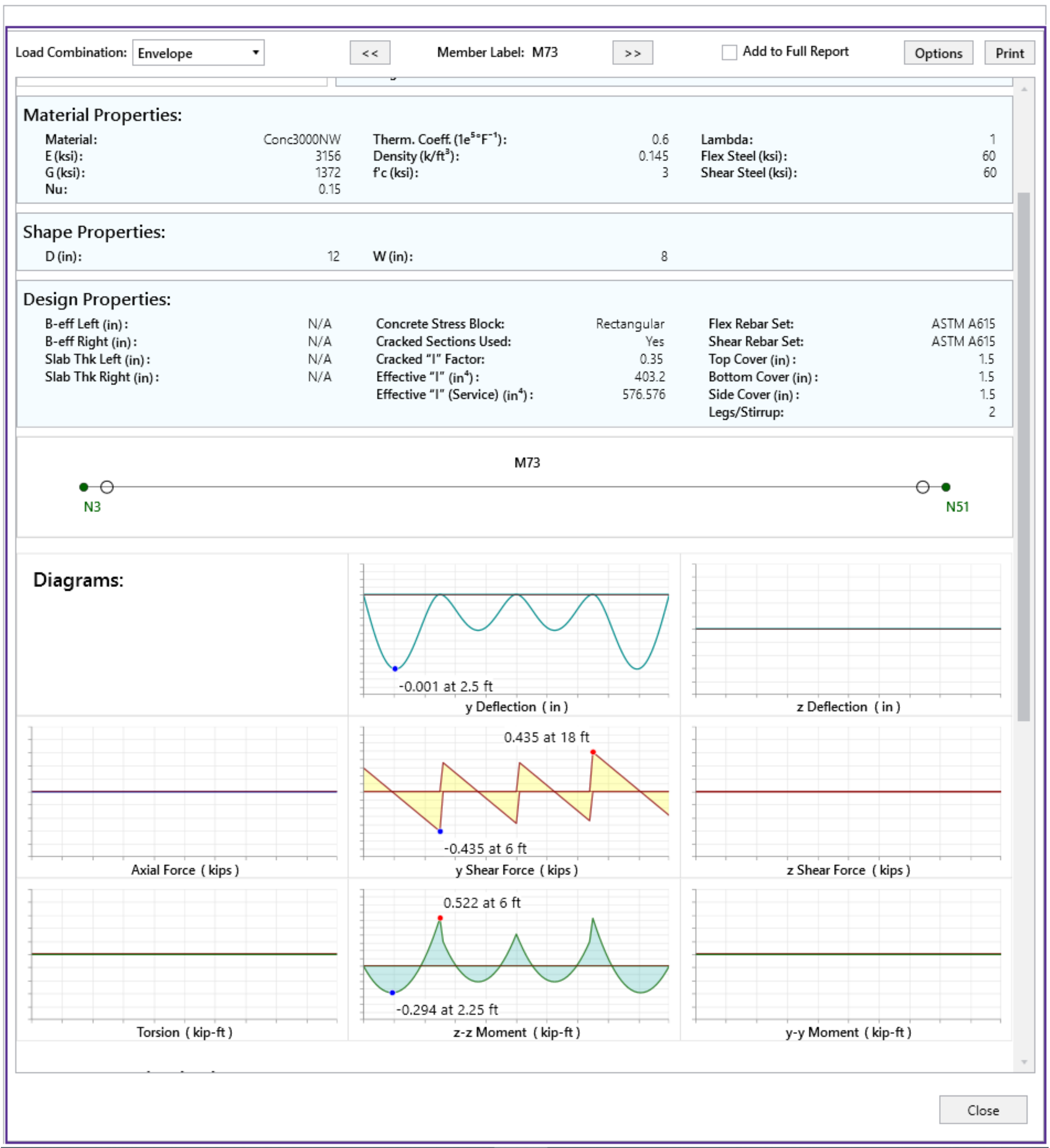

Figure 4. Structure report of one of the concrete beams under the five columns

The third of the five unique beams for this project are the wooden columns used to support the weight of the truss. These properties will also depend on the member analyzed as the leftmost columns will differ from the rightmost columns. This is due to the wind load applied to the leftmost columns causing a change in the shear force, moment, and bending compression stress whereas the rightmost columns would look slightly different from this. The structural analysis for one of the leftmost beams is shown in Figure 5 below.

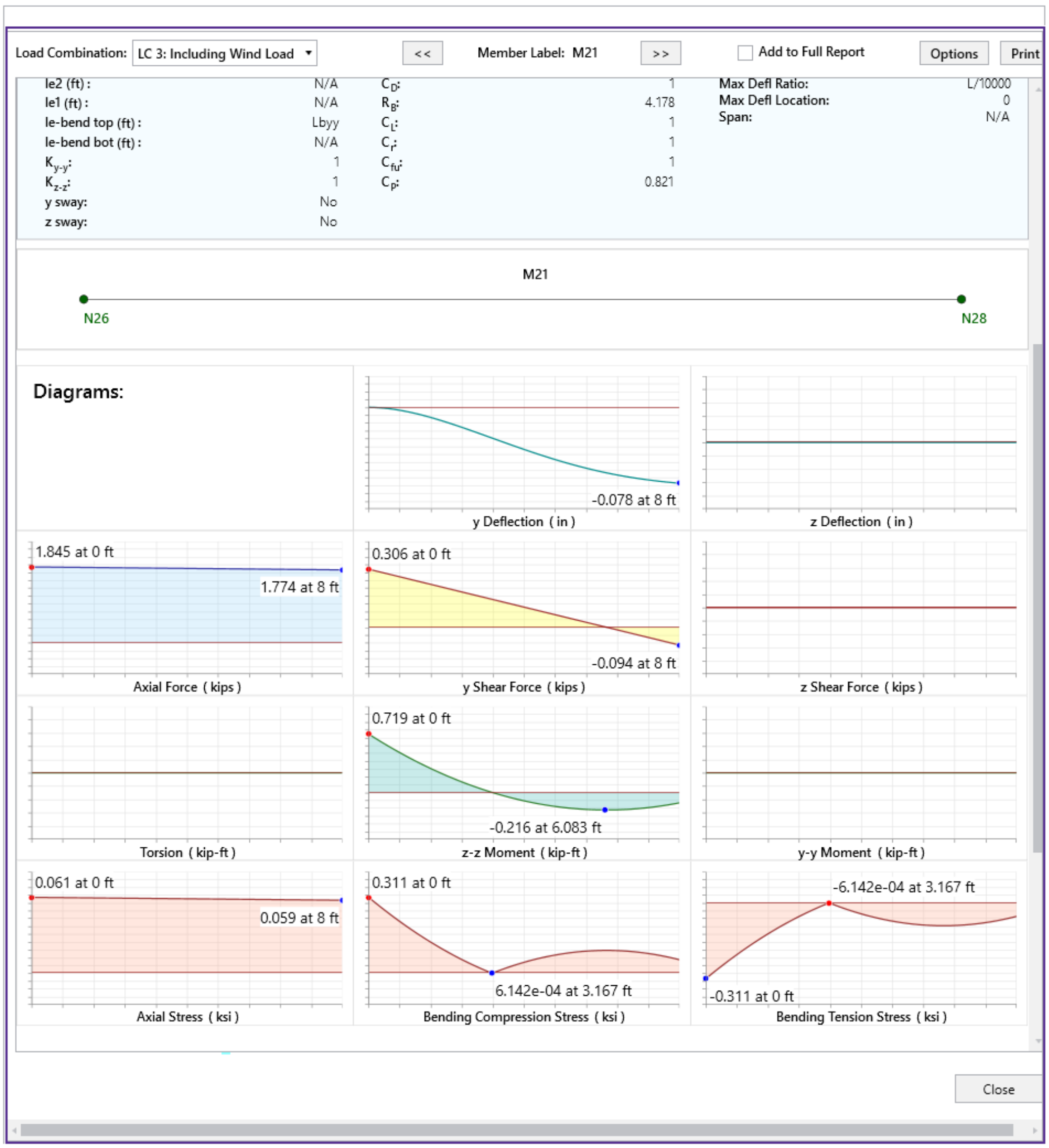

Figure 5. Structure report of one of the leftmost wooden columns

The fourth of the five unique beams are the members of the truss. These members are all made of the same material but the loads they carry may vary depending on their location within the truss. For example, the brace perpendicular to the bottom cable of the truss has no shearing force compared. However, other members of the truss do have axial forces such as the force perpendicular to the rightmost cable. The structural analysis for this member including the deflection, shearing force, and moment are shown in Figure 6.

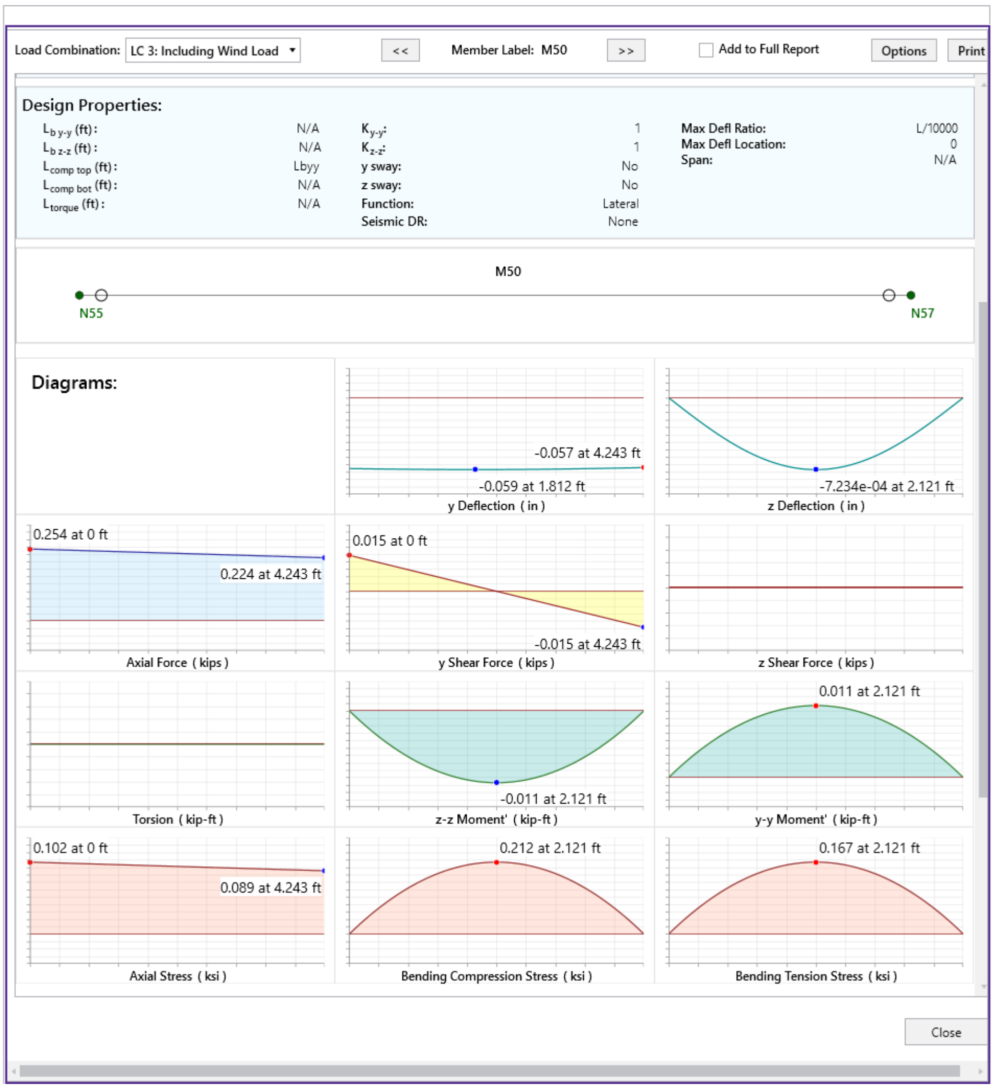

Figure 6. Structure report of one of the truss members

The fifth of the five unique beams are the purlins running overtop the trusses. These purlins have nearly identical properties between them except that the eight on the edge of the roof have a lighter live load resulting in less force acting on the beam. For the 12 purlins over the middle of the trusses, they all have the same loads and as a result, have the same defining features. These features are displayed in Figure 7 which display the shear force, moment, and other features of the beam.

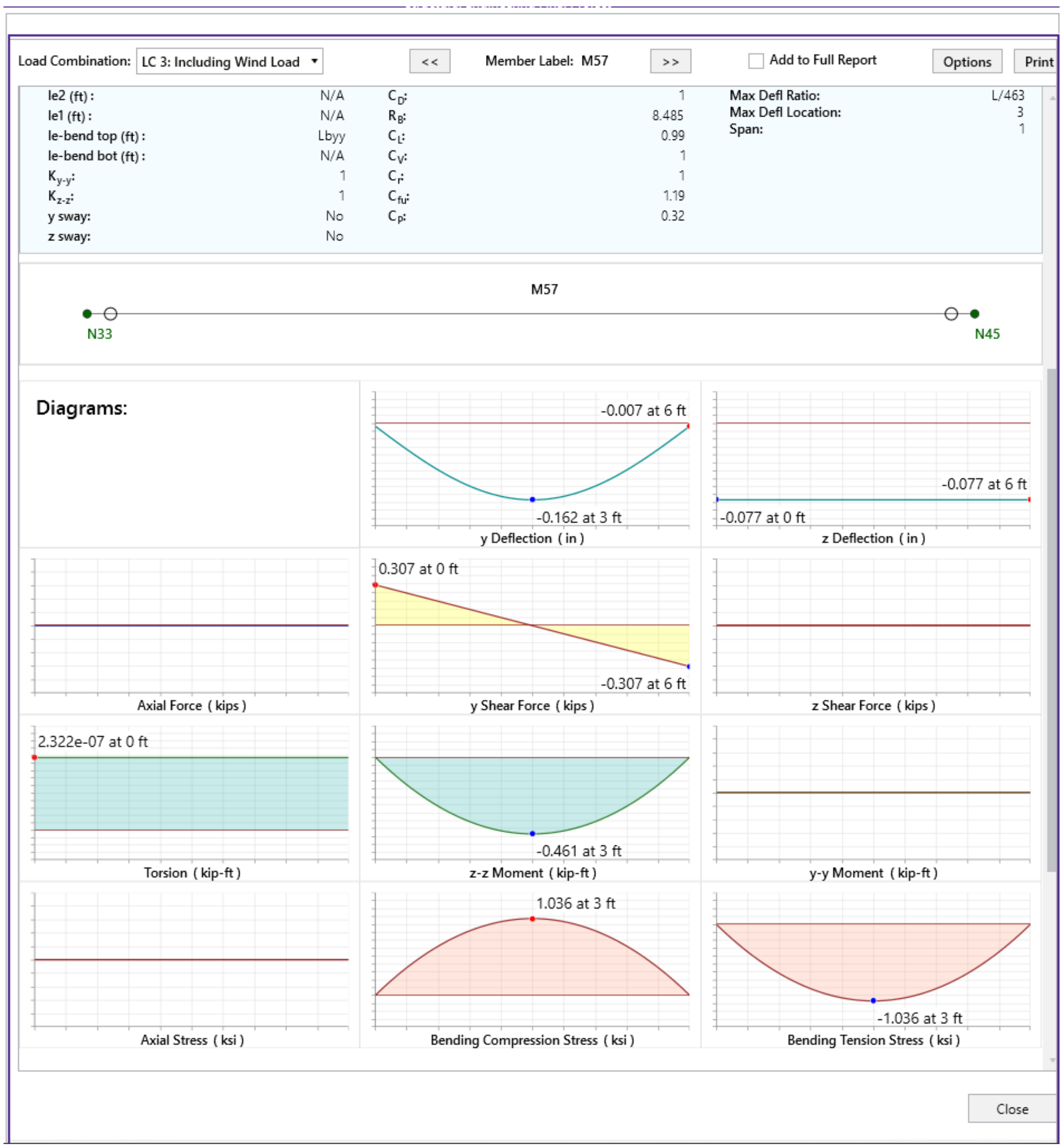

Figure 7. Structure report of one of the interior 12 purlins

The last feature of the structure is the overall deflection which can be seen in Figures 8 and 9. Figure 8 shows the deflection of the purlins resulting from the live load and snow load placed on the roof. Figure 9 shows the deflection of the entire structure due to the wind load applied on the five left most purlins. Both of these figures show an exaggerated version of the deflection, but the deflection never exceeds one inch at any point on the structure. The highest deflection happens at the middle of the purlins and the smallest deflection happens in the concrete columns which have no deflection. Note that the figures below show the combined loads once the safety factors have been determined and applied to the loads.

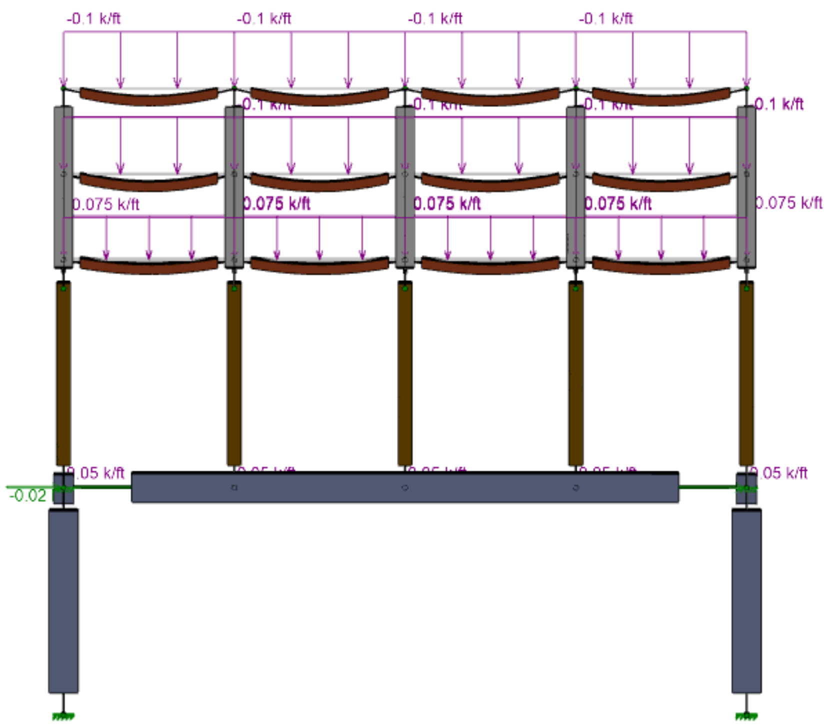

Figure 8. Visual representation of the deflection on the purlins

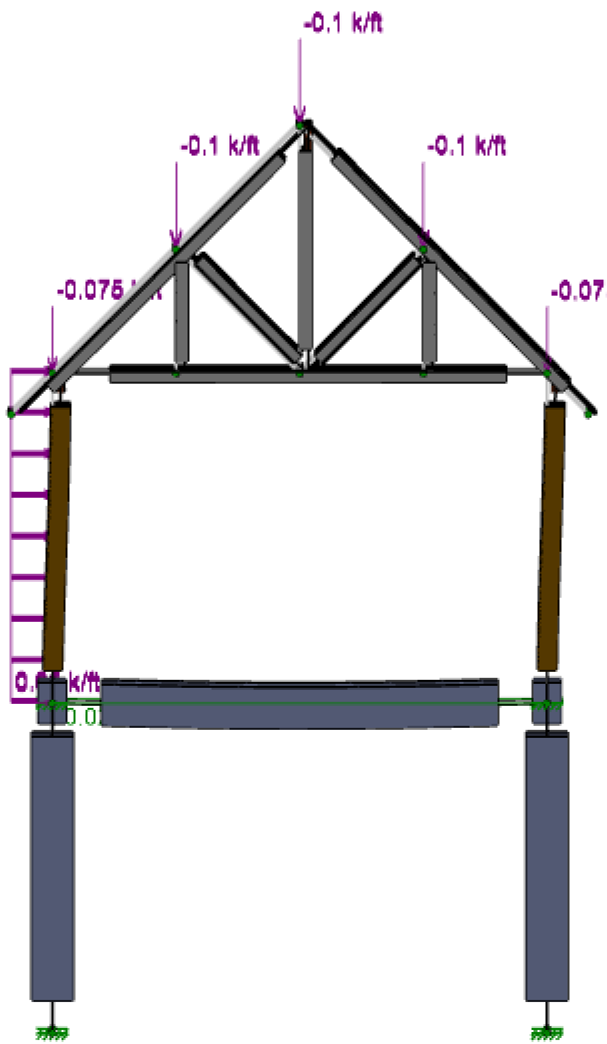

Figure 9. Visual representation of the deflection on the entire structure

Cost Analysis

The first step in assembling a cost analysis for this structure is to get a proper count of all the materials used. Using the material takeoff feature on RISA-3D, the amount of each material is properly counted and displayed. This count is displayed below in Figure 10. One notable aspect of the count is that different materials are measured in different units and this change is reflected in the price calculation. The concrete was measured in cubic yards while the wood and hot rolled steel were measured by unit length. Below are the final calculations for each material used in the design.

- Douglas Fir Wood 2” x 4” x 6’: $27.14 per piece * 20 pieces = $542.80
- Douglas Fir Wood 6” x 6” x 8’: $50.24 per piece * 10 pieces = $502.40
- Concrete 3000NW: $130 per cubic yard * 8.3 cubic yards = $1,079
- Hot Rolled Steel A36 Gr. 36: $539 per ton * 1.788 tons = $963.73
- Total Material Price: $3,087.93

Material Takeoff

	Material	Size	Pieces	Length[ft]	Weight[K]
1	Hot Rolled Steel				
2	A36 Gr.36	L3.5X3.5X6	25	102.4	0.871
3	A36 Gr.36	LL3.5x3.5x6x3	15	159	2.705
4	Total HR Steel		40	261.4	3.576
5					
6	Wood				
7	24F-1.8E DF Balan...	2X4FS	20	120	0.233
8	DF	6X6	10	80	0.588
9	Total Wood		30	200	0.822
10					
11	Concrete Members			Volume (yds...	
12	Conc3000NW	CRECT12X12	4	1.2	4.64
13	Conc3000NW	CRECT12X8	4	1.8	6.96
14	Total Concrete		8	3	11.6
15					
16	Plate Elements	Thickness (in)		Volume (yds...	
17	gen_Conc3NW	6	1	5.3	20.88
18	Total Plates		1	5.3	20.88

Figure 10. A total count of all the materials used in the 3D rendering.

Not accounted in the list above is the labor cost required for a project of this size and the total cost for this project could range from $5,000 to $10,000. A few of the factors that can vary this price include the number of workers, the quality of the workers, and the utilities needed for the project.

Conclusion

The process of creating a structure provided invaluable insight into the traditional design process for any kind of building. This process involved brainstorming for a structure to design, creating the plans, modeling the structure, as well as analyzing it once complete. Assuming most of this is done correctly, the building stands under its own power while successfully supporting all of the design loads. RISA even provides detailed models and results which provide further insight into what is happening to each member of the structure depending on what loads are applied.