Structural Engineering

CIVL 310

Prepared For:

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Prepared By:

C.T

RISA Final Project Structural Analysis Report

Abstract

This final report will discuss my project, which consists of creating a floor plan and 3D model of a structure that has elements of wood, concrete, and steel used within the design of the structure. I chose to structurally design and analyze my house for my final project. This report will display the floor plan that I created in AutoCAD, and it will show data collected by RISA software.

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Dimensions

To begin my project, I have retrieved measurements of the layout of my house from documents given to my parents when they moved into the house (Fig. 1). The house consists of four bedrooms and a bathroom upstairs, and a kitchen, living room, dining room, foyer, attic, and basement. The house is 30-feet by 28.2-feet, which yields an area of 846-square-feet for each floor.

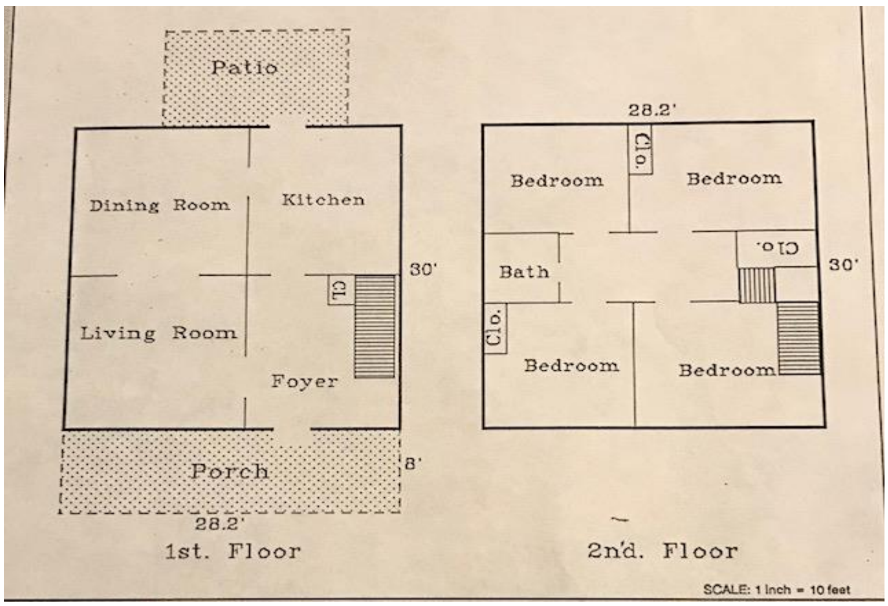


Figure 1. Floor plan dimensions of the house.

AREA CALCULATIONS SUMMARY

Area	Name of Area	Size	Totals
GLA1	First Floor	846.00	846.00
GLA2	Second Floor	846.00	846.00
POR	Porch	225.60	
	Porch	160.00	385.60
TOTAL LIVABLE (rounded)			1692

LIVING AREA CALCULATIONS

Breakdown			Subtotals
28.20	x	30.00	846.00
0.65	x	0.10	0.07
28.20	x	30.00	846.00
0.65	x	0.10	0.07
			1692

Figure 2. Calculated area of each floor within the house.

Floor Plan

Using this given data, I created a floor plan using AutoCAD software. This allows me to find more dimensions for the house, in which I can use to model the structure onto RISA. I created a floor plan of the floor layouts, as well as where doors, stairs, and columns are located (Fig. 3).

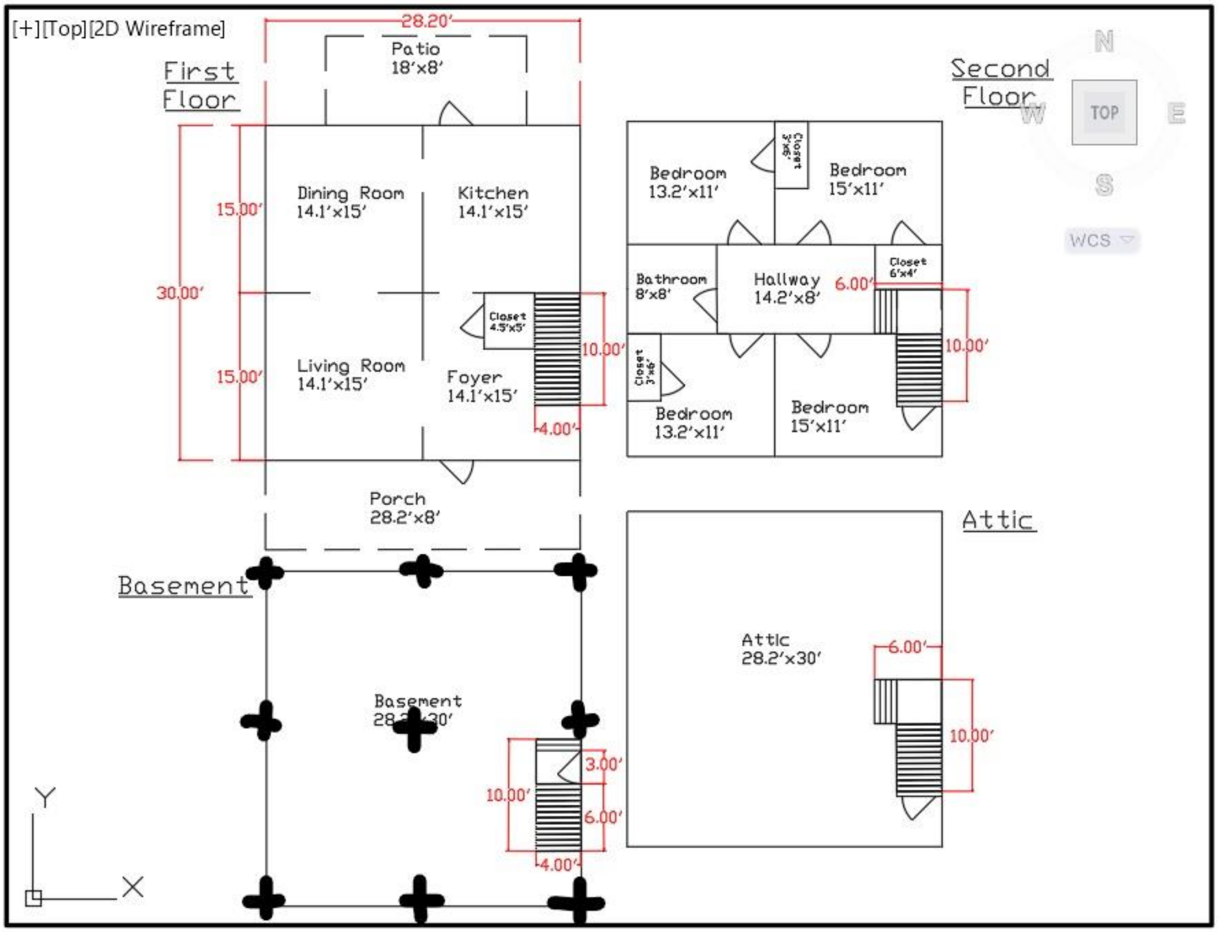
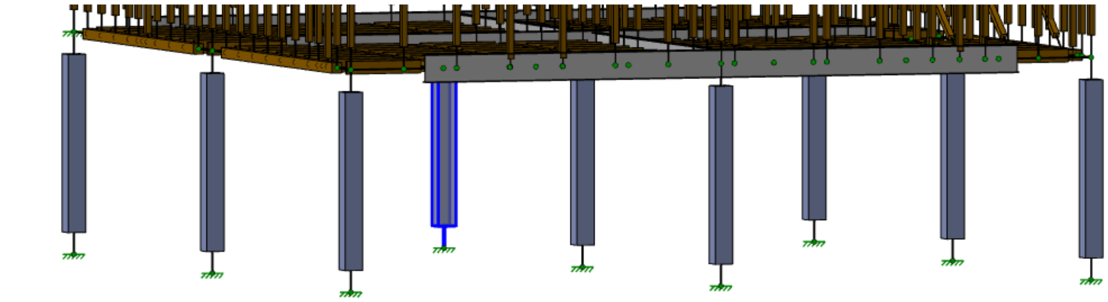


Figure 3. Floor plan of designed on AutoCAD, plus marks are where concrete columns are located to support the house.

Modeling

The new floor plan gives me dimensions to create an accurate 3D model of the structure. The structure's foundation is built with 3000NW concrete columns that support the structure. The space withing the columns acts as the basement of the house. The concrete columns are rectangular 8-inch by 8-inch columns that stand 8-feet tall (Fig. 4). The concrete columns have fixed boundary conditions to where they are connected to the ground.



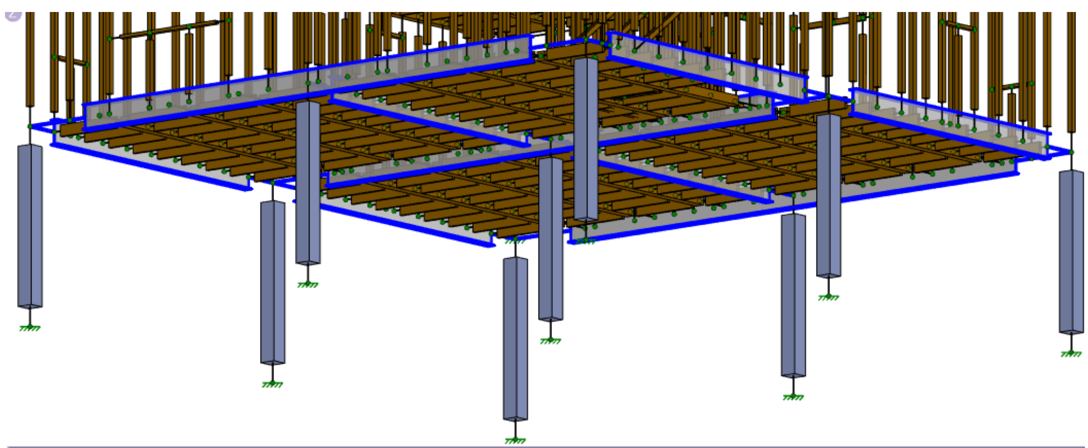
Concrete Section Sets

Hot Rolled | Cold Formed | Wood | Concrete | Aluminum | Stainless | General

	Label	Shape	Type	Design List	Material	Design Rule	Area [in^2]	Iyy [in^4]	Izz [in^4]	J [in^4]
1	Column	CRECT8X8	Column	Rectangular	Conc3000NW	Typical	64	341.333	341.333	505.173

Figure 4. Nine concrete columns located in the basement of the house.

The concrete columns connect to the A992 hot rolled steel girders and beams that support a majority of the load acting from the wood supports of the house. The steel girders and beams are wide flanged, which prevents deflection of the beam (Fig. 5). The steel beams will support more weight due to the weight of the walls on the edges of the house.



Hot Rolled Steel Section Sets

Hot Rolled | Cold Formed | Wood | Concrete | Aluminum | Stainless | General

	Label	Shape	Type	Design List	Material	Design Rule	Area [in^2]	Iyy [in^4]	Izz [in^4]	J [in^4]
1	Bsmt. Girder	W12X16	Beam	Wide Flange	A992	Typical	4.71	2.82	103	0.103
2	Bsmt. Beam	W12X16	Beam	Wide Flange	A992	Typical	4.71	2.82	103	0.103

Figure 5. Three steel girders stretching across the bottom level of the house, with four steel beams coming off the steel girders.

The rest of the structure consists of DF wood studs, girders, and beams. All of the wood within the structure has a rectangular shape. Each section set has different cross-sectional areas because of their purposes withing the structure. There are several types of labeled wood identifications used for how each section of wood is oriented differently (Fig. 6).

Wood Section Sets

Hot Rolled | Cold Formed | Wood | Concrete | Aluminum | Stainless | General

	Label	Shape	Type	Design List	Material	Design Rule	Area [in^2]	Iyy [in^4]	Izz [in^4]	J [in^4]
1	Stud	3X3	Column	Rectangular	DF	Typical	6.25	3.255	3.255	5.501
2	Girder	3X6	Beam	Rectangular	DF	Typical	13.75	7.161	34.661	20.472
3	Beam	5X5	Beam	Rectangular	DF	Typical	20.25	34.172	34.172	57.75
4	Bracing	3X3	VBrace	Rectangular	DF	Typical	6.25	3.255	3.255	5.501
5	Header	2X3	Beam	Rectangular	DF	Typical	3.75	0.703	1.953	1.761
6	Footer	3X3	Column	Rectangular	DF	Typical	6.25	3.255	3.255	5.501
7	Joist	2X6	Beam	Rectangular	DF	Typical	8.25	1.547	20.797	5.125
8	Truss Be...	4X4	Beam	Rectangular	DF	Typical	12.25	12.505	12.505	21.134
9	Truss St...	2X2	Column	Rectangular	DF	Typical	2.25	0.422	0.422	0.713
10	Truss Di...	2-2X4	VBrace	Rectangular Do...	DF	Typical	10.5	7.875	10.719	15.255

Figure 6. Wood section sets used in the structure such as beams, columns, and vertical braces.

Usually studs are 1.5-feet apart from each other, so when I created the model, I used the global tool to make multiple copies of the studs that are distance the same amount apart from each other. The internal and external walls of the house consist of these studs that are 1.5-feet apart and that stand 8-ft tall (Fig. 7).

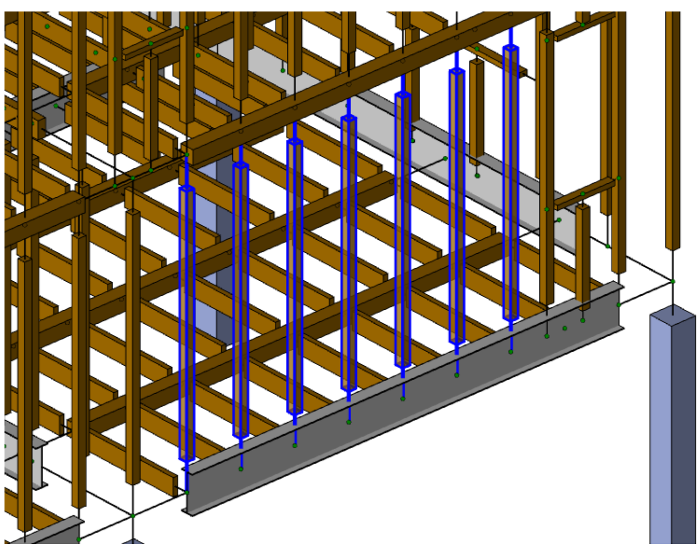


Figure 7. The external wall on the first floor of the house.

Along with the studs, there are window frames and door frames placed within the house (Fig. 8). The frames are made from footers and headers. There are also two staircases within the house that are supported by studs and braces (Fig. 9). The roof consists of multiple trusses in order to support live loads that act on the house (Fig. 10). The floors of the house have wooden joists in between the wooden beams as well for extra support (Fig. 11).

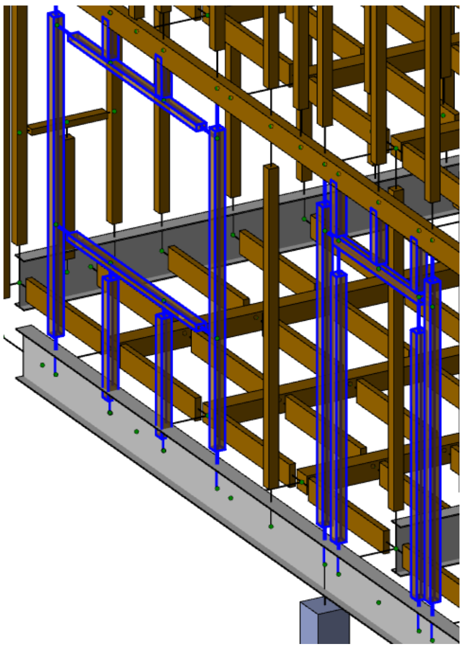


Figure 8. Door frame and window frame.

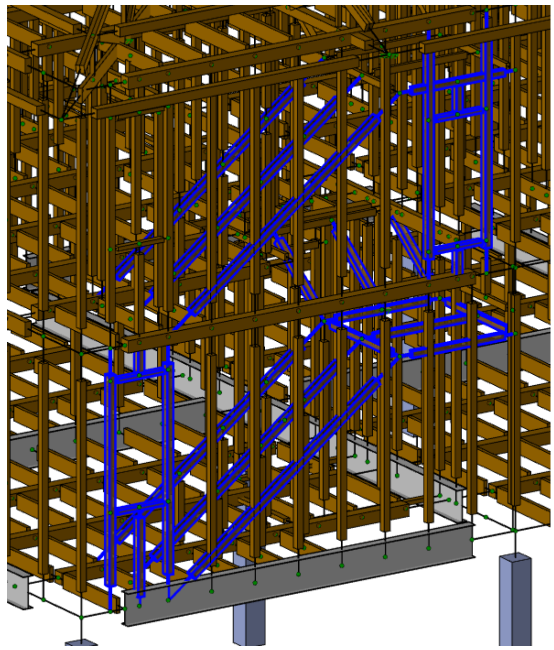


Figure 9. Stairs framing and window frames.

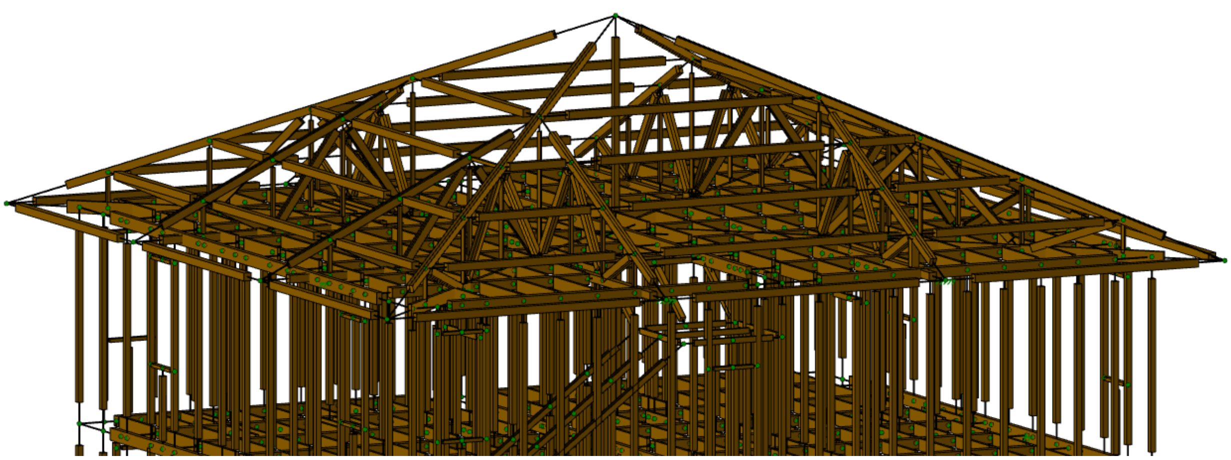


Figure 10. Roof trusses used to support live loads acting on roof.

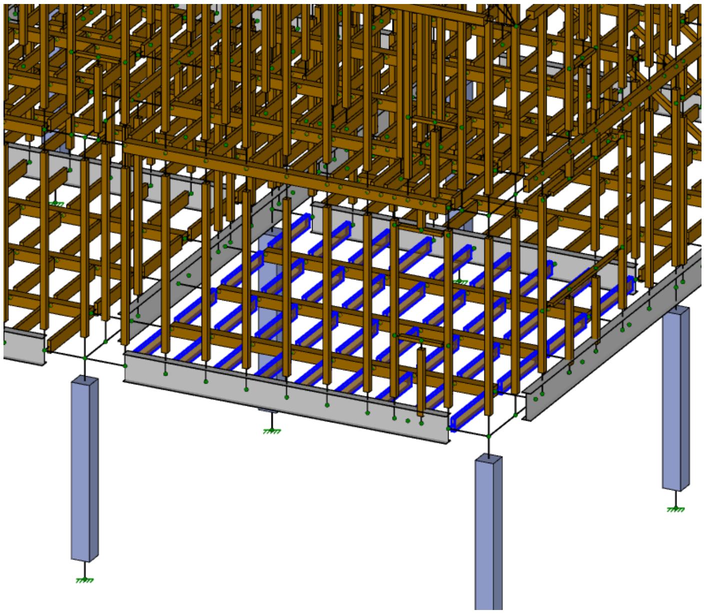


Figure 11. Wooden joists to support floors.

The structure is supported with many pins and fixed boundary conditions. The structure can support the dead load of itself as well as live loads such as rain, snow, and moving loads. The structure itself is 24-feet tall. The house is built with all of the materials required for the project and contains over a thousand members (Fig. 12).

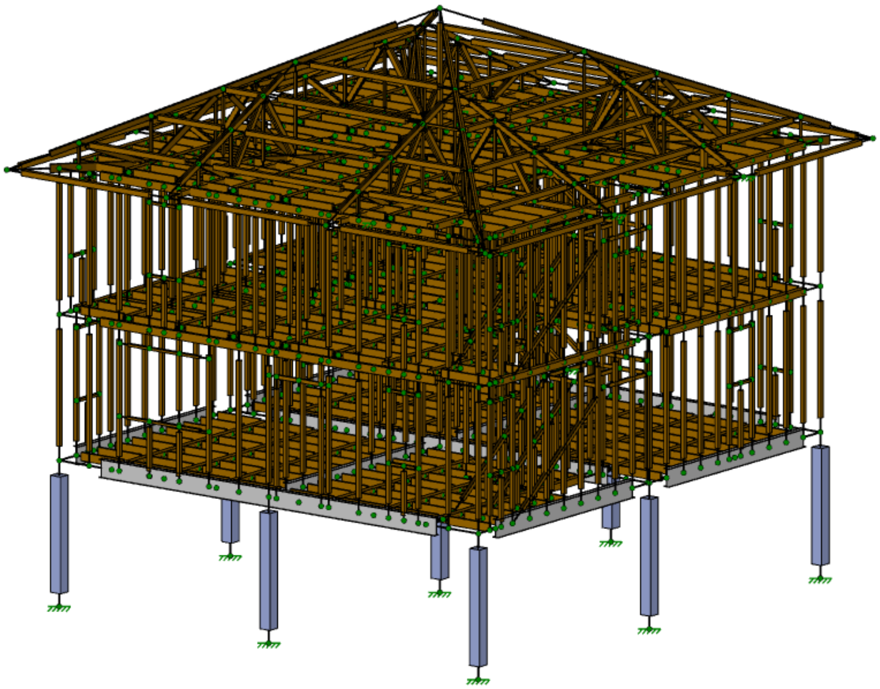


Figure 12. Finalized 3D model of the house.

Structural Analysis

The concrete columns hold all of the dead load of the house and any live loads that act on the house also. The central concrete column has deflection in both the y-direction and z-direction, but no shear force in those directions (Fig. 13). When compared to the concrete columns on the corners of the house, these columns do have shear force in both y-direction and z-direction, and moment in both y-direction and z-direction also (Fig. 14).

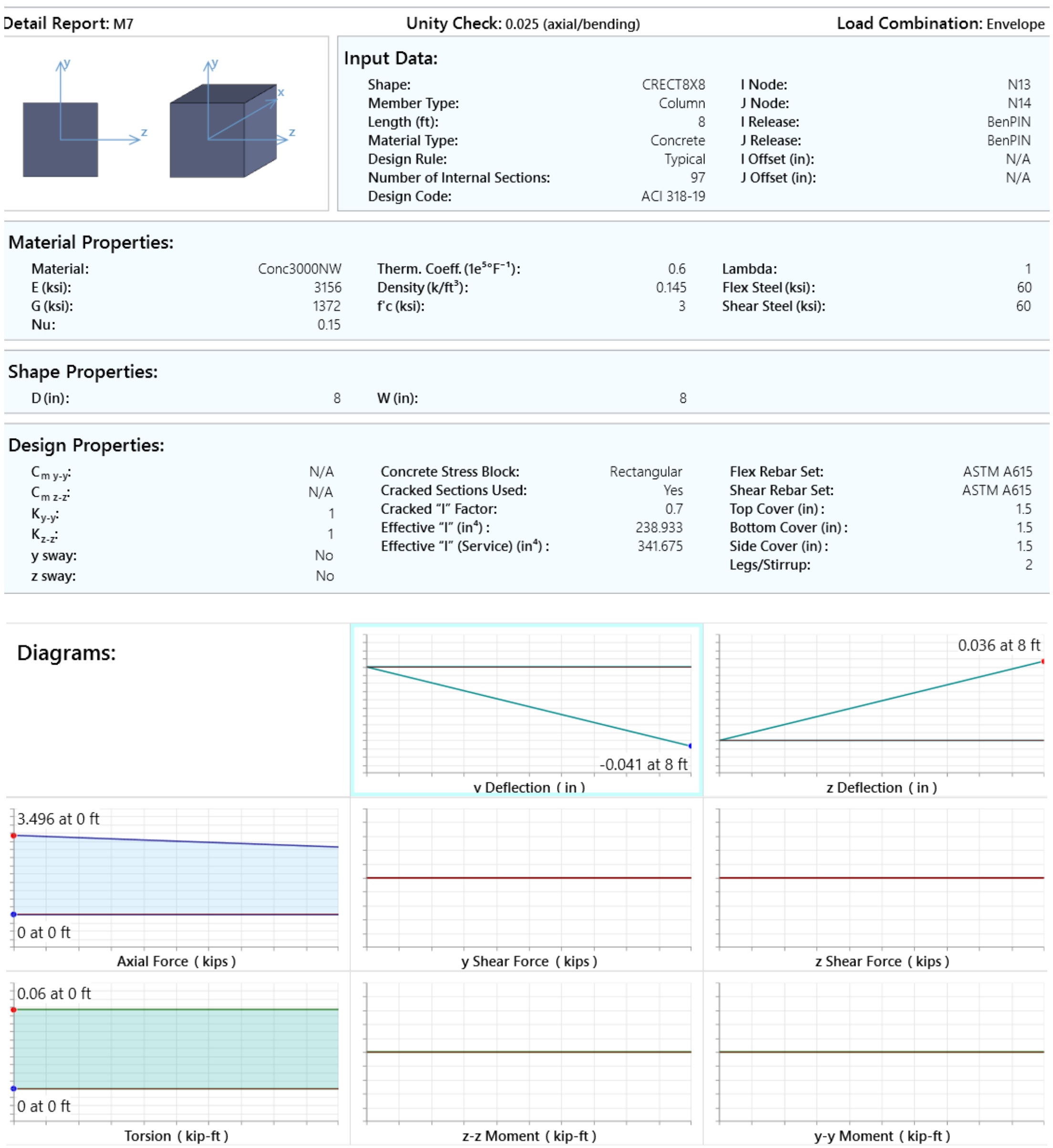


Figure 13. Data from central concrete column.

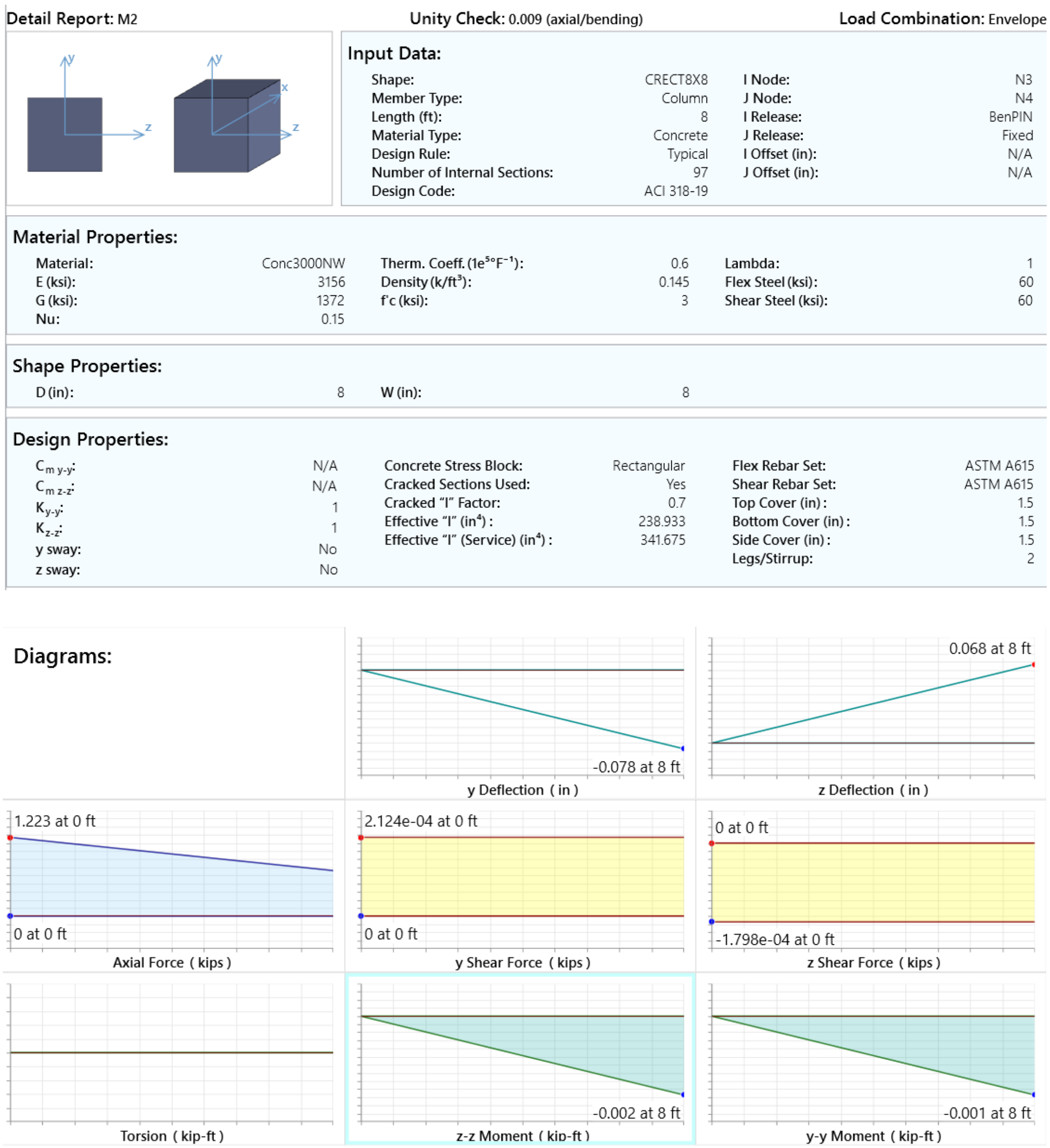
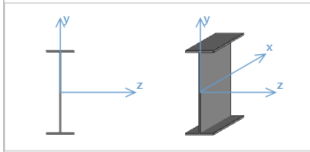


Figure 14. Data from corner concrete column.

The steel girders and beams are wide-flanged which would prevent any possible buckling. They are very strong supports for the rest of the house and its wood sections. The steel girder in the center of the house has a great amount of force acting on it, as seen in the diagrams (Fig. 15). The diagrams show that there is deflection, shear and moment in the y-direction and z-direction. The steel girder on the edge has las forces acting on it, but still enough for there to be deflection, shear, and moment in both the y-direction and the z-direction (Fig. 16).

Detail Report: M11 **Unity Check:** 0.46 (axial/bending) **Load Combination:** LC 1: DL+LL



Input Data:

Shape:	W12X16	I Node:	N8
Member Type:	Beam	J Node:	N6
Length (ft):	28.2	I Release:	BenPIN
Material Type:	Hot Rolled Steel	J Release:	BenPIN
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	97	J Offset (in):	N/A

Material Properties:

Material:	A992	Therm. Coeff. ($1e^{5}$°F^{-1}):	0.65	R_y:	1.1
E (ksi):	29000	Density (k/ft^3):	0.49	F_u (ksi):	65
G (ksi):	11154	F_y (ksi):	50	R_t:	1.1
Nu:	0.3				

Shape Properties:

d (in):	12	Area (in^2):	4.71	S_w (in^4):	3.09
b_f (in):	3.99	Z_{yy} (in^3):	2.26	r_T (in):	0.964
t_f (in):	0.265	Z_{zz} (in^3):	20.1	J (in^4):	0.103
t_w (in):	0.22	C_w (in^6):	96.9	k_{det} (in):	0.812
I_{yy} (in^4):	2.82	W_{no} (in^2):	11.7	k_{des} (in):	0.565
I_{zz} (in^4):	103				

Design Properties:

$L_{b\ y\text{-}y}$ (ft):	N/A	$K_{y\text{-}y}$:	1	Max Defl Ratio:	L/10000
$L_{b\ z\text{-}z}$ (ft):	N/A	$K_{z\text{-}z}$:	1	Max Defl Location:	0
$L_{comp\ top}$ (ft):	Lbyy	y sway:	No	Span:	N/A
$L_{comp\ bot}$ (ft):	N/A	z sway:	No		
L_{torque} (ft):	N/A	Function:	Lateral		
		Seismic DR:	None		

Diagrams:

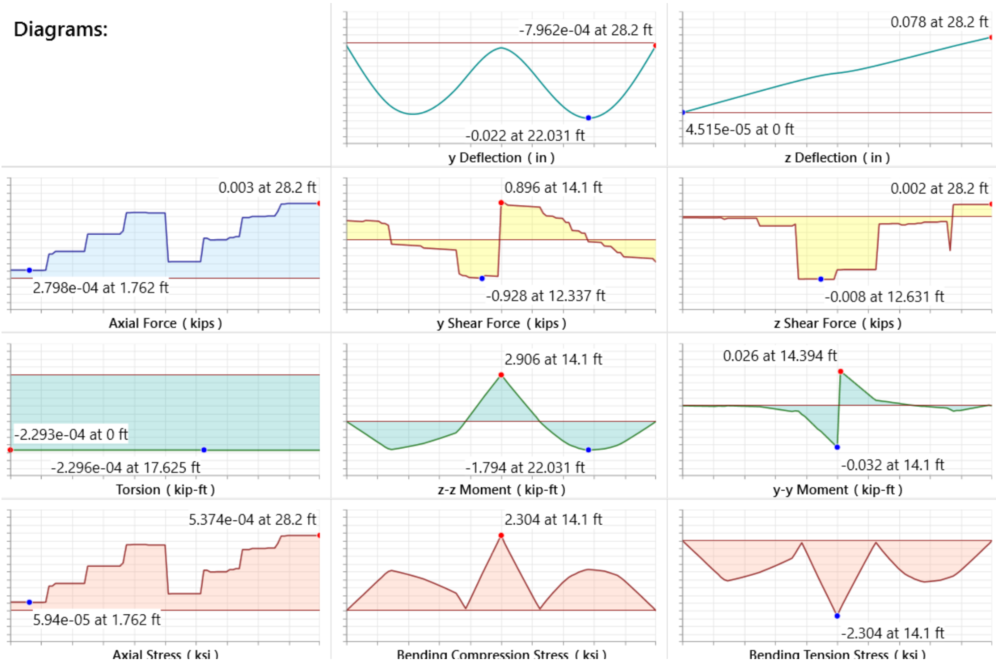


Figure 15. Data collected from central steel girder.

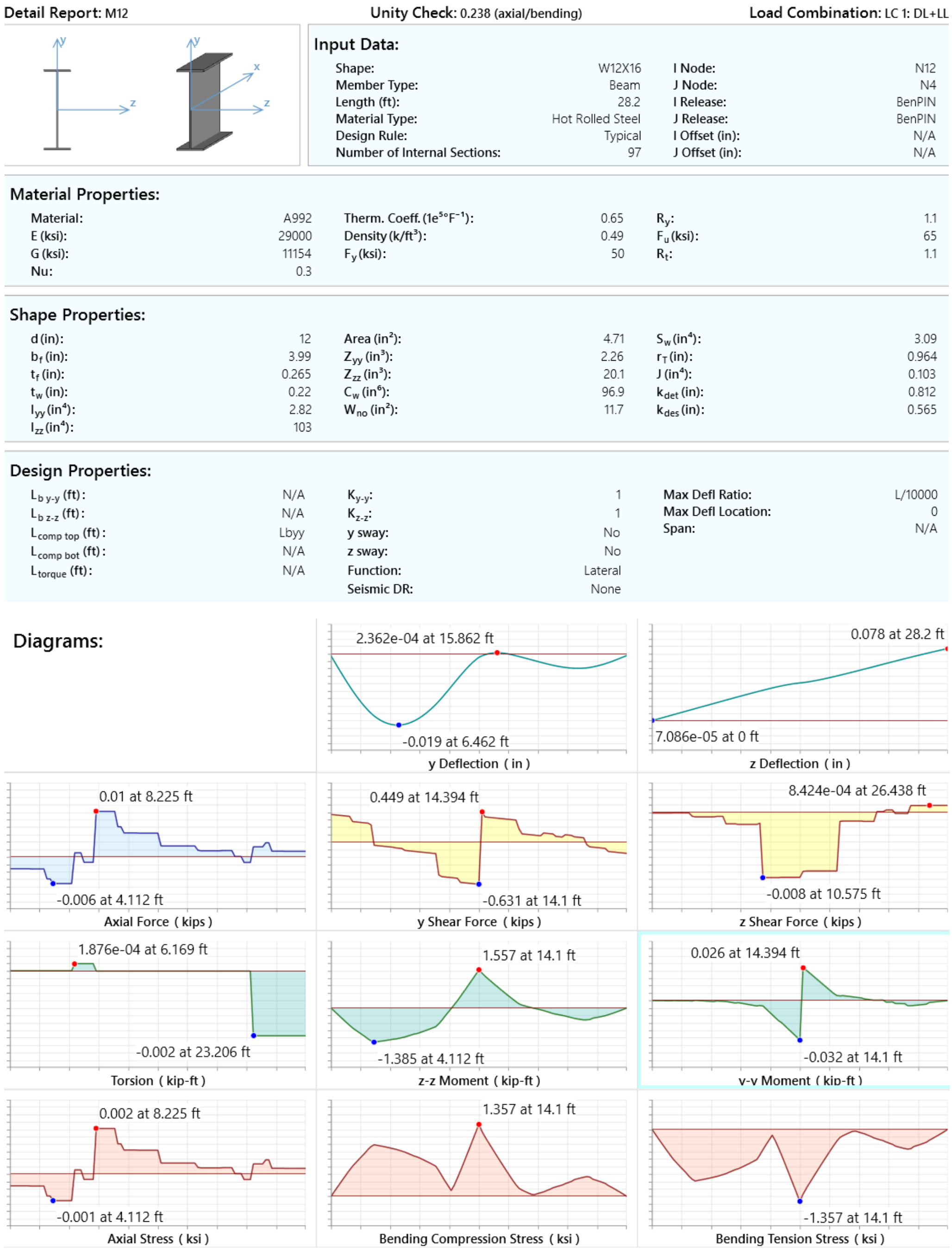


Figure 16. Data collected from right edge steel girder.

There are a lot of wooden member throughout the entire structure that have similar properties, so I will give information on only some of the members. I have gathered information on the central wooden stud on the first floor, the corner stud on the first floor, the wooden girder of the second floor, the wooden beam of the first floor, the wooden joist of the first floor, the wooden stud in the attic and the wooden diagonal truss of the roof support. The central wooden stud within the first floor shows deflection and shear in both directions (Fig. 17).

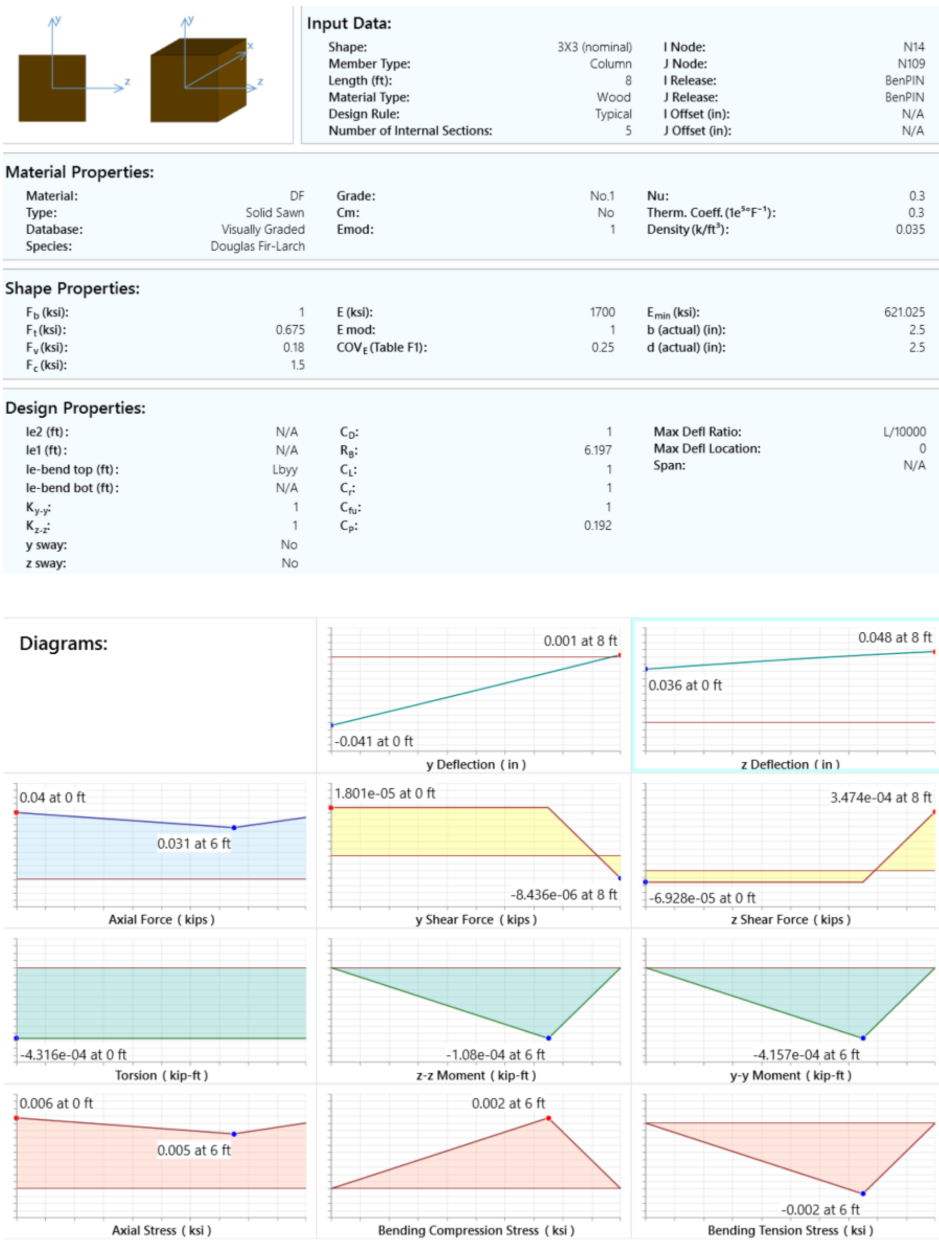


Figure 17. Data collected from central wooden stud on first floor.

The wooden stud located at the corner of the house on the first floor gives different data in comparison to the wooden stud in the central part of the house on the first floor. The wooden stud has deflection in both directions but shows no signs of shear force in any of the directions (Fig. 18).

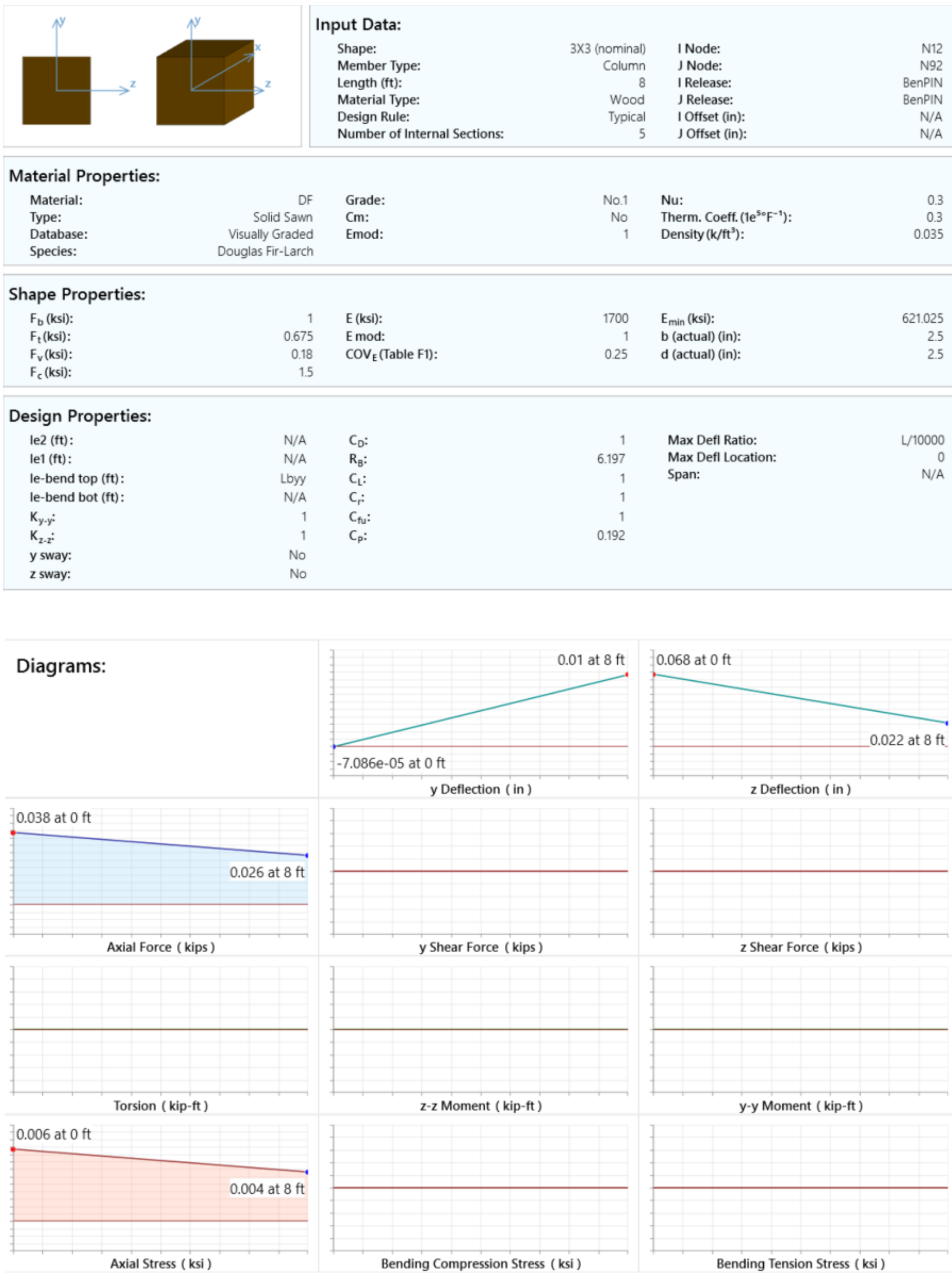


Figure 18. Data collected from corner wooden stud on first floor.

The wooden girder on the second floor has many members attached to it so it should receive a great amount of external force. There is deflection and shear forces present within the member, as well as moment (Fig. 19).

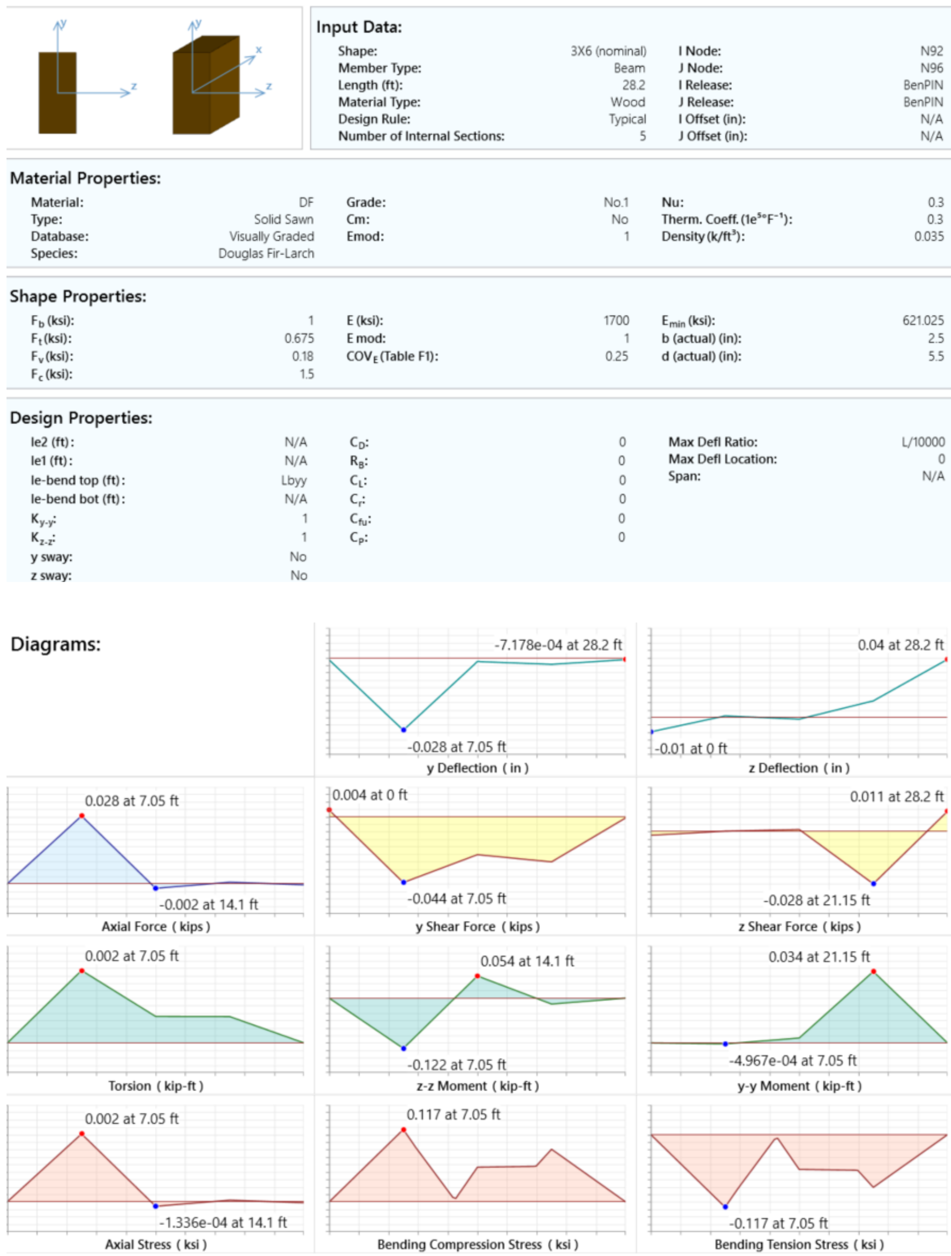


Figure 19. Data collected from wooden girder on second floor.

The wooden beam located on the first floor of the house holds the joists of the floor and is attached to the steel beams of the first floor. The girder has deflection in the y-direction that appears to be symmetrical due to having wooden joists attached to the member symmetrically in each direction. Shear force and moment is present in each of the directions also (Fig. 20).

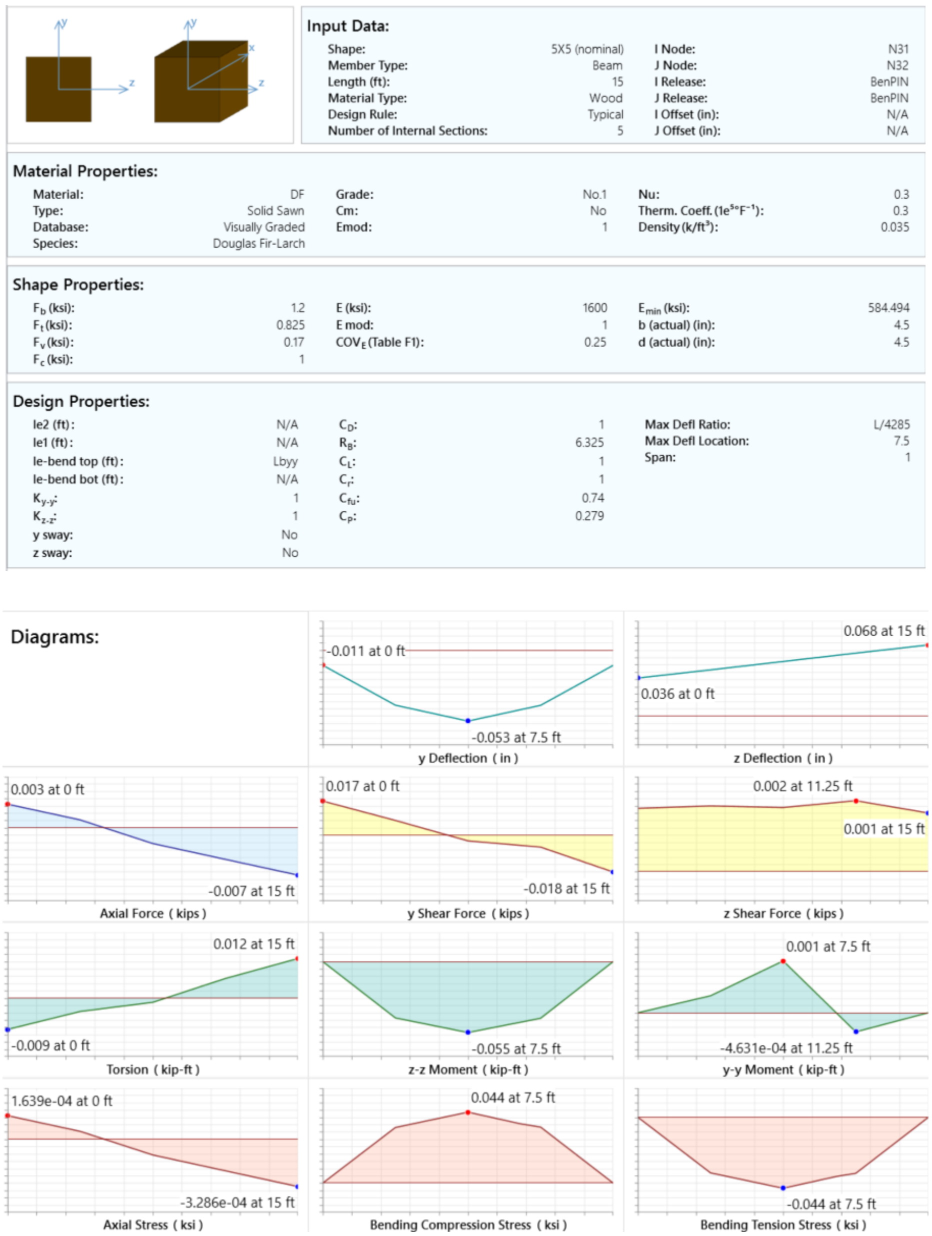


Figure 20. Data collected from wooden beam on the first floor.

The wooden joist between each of the wooden beams are there to support the weight from the floor and the live loads that could possibly act on it. The joists have identical data with each other throughout the structure. Each joist has deflection, shear force, and moment within them (Fig. 21).

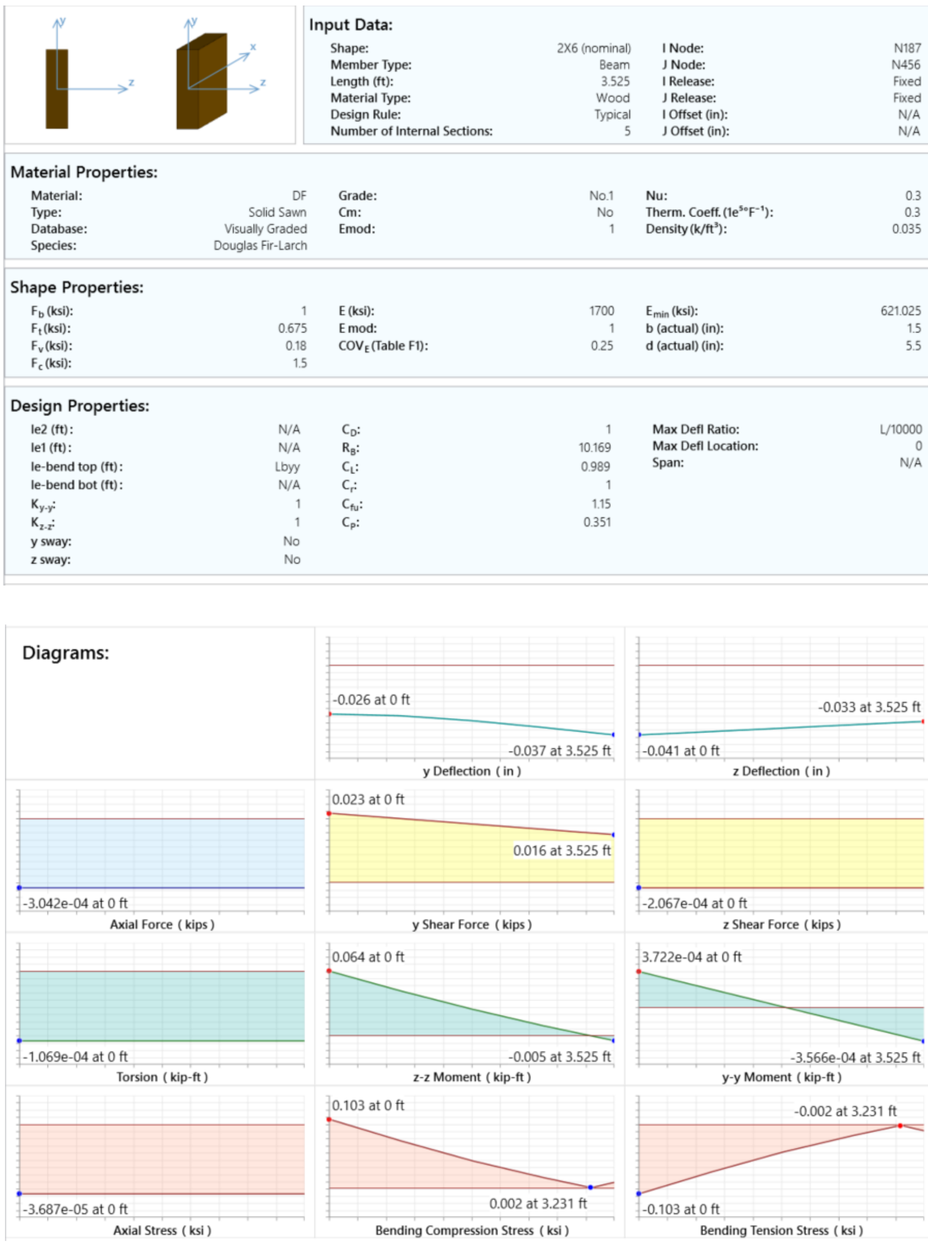


Figure 21. Data collected from wooden joist on the first floor.

The wooden stud that is located in the center of the attic is connected to each of the diagonal trusses of the roof. There is deflection within the member, but there is also moment that is greater more at the top of the stud and then it decreases as it reaches the bottom support of the stud (Fig. 22).

Figure 22. Data collected from wooden stud in the attic.

The truss of the roof is where the live load is specifically located. The live load acts on the roof and the forces are distributed throughout the rest of the members of the house. The truss has deflection, shear, and moment form the dead load and live load, as well as the supports of the other parts of the truss acting on it (Fig. 23).

Figure 23. Data collected from wooden truss from roof.

The roof trusses support a combination of both dead load and live load. The live load primarily acts on the beams of the connecting trusses with an estimated load of -0.2 k/ft (Fig 24). Dead load is applied to every member of the structure, due to each member's own weight.

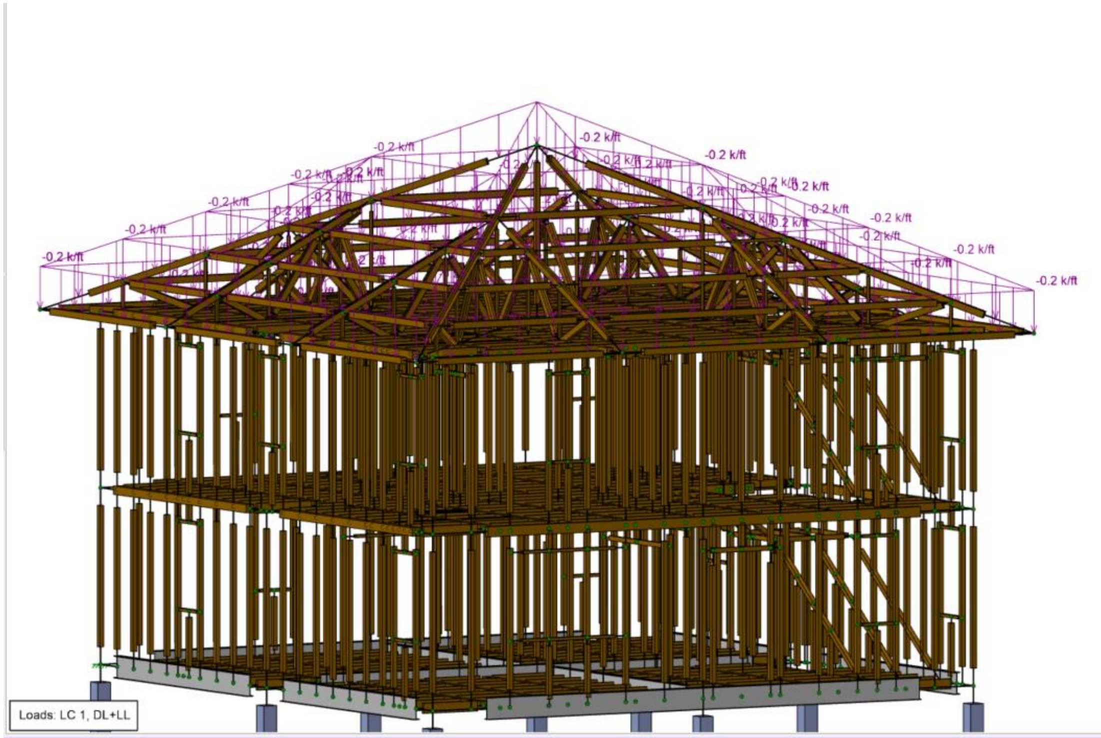


Figure 24. Load combination of the structure, mainly the live load acting on roof trusses.

Cost Analysis

The structure has hot rolled steel, wood, and concrete used for the design. The estimated cost can be calculated using the information given from the material takeoff tab in RISA. This gives us the information about the material, size, number of pieces, length, and weight of each of the members (Fig. 25). Using different sources, I found the price of the different sizes of steel, wood, and concrete needed to construct the structure. The total cost of the project's framework equates to an estimate of $18,711.79 (Fig 26). This does not include the cost to construct walls, floors, or any utilities needed in the structure.

Material	Size	Pieces	Length[ft]	Weight[K]
Hot Rolled Steel				
A992	W12X16	9	174.6	2.798
Total HR Steel		9	174.6	2.798
Wood				
DF	5X5	49	710	3.495
DF	3X3	341	2263	3.438
DF	3X6	6	169.2	0.565
DF	2X3	70	212.7	0.194
DF	2X6	432	1588.9	3.186
DF	2-2X4	48	360.5	0.92
DF	2X2	40	118.7	0.065
DF	4X4	60	528.2	1.573
Total Wood		1046	5951.2	13.436
Concrete Members			Volume (yds...	
Conc3000NW	CRECT8X8	9	1.2	4.64
Total Concrete		9	1.2	4.64

Figure 25. Material takeoff of the structure.

Material	Size	Pieces	Length[ft]	Weight[K]	Weight[lb] per Length[ft]	Cost per Piece	Total Cost for Pieces
Hot Rolled Steel							
A992	W12X16	9	174.6	2.798	16.025		
Total HR Steel		9	174.6	2.798	16.025	$ 674.19	$ 6,067.71
Wood	Size	Pieces	Length[ft]	Weight[K]	Length[ft] per Piece		
DF	5X5	49	710	3.495	14.5	$ 39.98	$ 1,959.02
DF	3X3	341	2263	3.438	6.6	$ 15.62	$ 5,326.42
DF	3X6	6	169.2	0.565	28.2	$ 46.98	$ 281.88
DF	2X3	70	212.7	0.194	3.0	$ 2.98	$ 208.60
DF	2X6	432	1588.9	3.186	3.7	$ 5.18	$ 2,237.76
DF	2-2X4	48	360.5	0.92	7.5	$ 4.25	$ 204.00
DF	2X2	40	118.7	0.065	3.0	$ 3.48	$ 139.20
DF	4X4	60	528.2	1.573	8.8	$ 15.62	$ 937.20
Total Wood		1046	5951.2	13.436			$ 11,294.08
	Size	Pieces	Length[ft]	Weight[K]			
Concrete Members			Volume (yds^3)			Cost per Cubic Yard (yd^3)	Total Cost for Pieces
Conc3000NW	CRECT8X8	9	1.2	4.64		$ 125.00	$ 1,350.00
Total Cost:							
$ 18,711.79							

Figure 26. Cost estimate of the materials needed to construct the house.

Conclusion

The structure was designed starting with a floor plan, then moving onto creating a 3D model of the structure, and then going through structural analysis using RISA. The process of designing the structure deals with a lot of detailed steps and calculations. The structure successfully stands, and RISA gives good, detailed data about the characteristics and properties of each of the members built within the structure. The project gives me a better understanding of how programs like AutoCAD and RISA work, and how to fix issues with different types of situations when designing.