Structural Engineering

ENGR 310

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Executive Summary

The purpose of this final report is to summarize the final structural project. This project consisted of creating a floor plan using AutoCAD and a 3D model of a structure using RISA 3D. It is required that the structure contains steel members, wood members, and concrete members. The inspiration of this project came from the 1989 cartoons *The Simpsons*. The structure in this project is supposed to model the Simpson's home shown in the TV series.

Floor Plan

1. First Story Floor Plan

The floor plan was designed using AutoCAD 2021 software. The floor plan was created to represent the dimensions of the rooms on the first floor as well as the dimensions of the house itself. Dimensions of the house and rooms come from design of the cartoon house on the TV show The Simpsons. This house is 32-feet by 51-feet with 18-feet by 24-feet two car garage. The height of the walls are 8 feet, which is typical in residential homes. Purposes of the rooms are labeled in the floor plan (Figure 1 & 3). Column placement of the foundation as well as the first story is represented with red squares (Figure 2 & 4). Foundation columns are rectangular 10-inch by 12-inch made of concrete and first and second story columns are 8-in by 10-in wide flange made of hot rolled steel. Columns were place at corners of the rooms as well as the middle of the walls of the rooms for support.

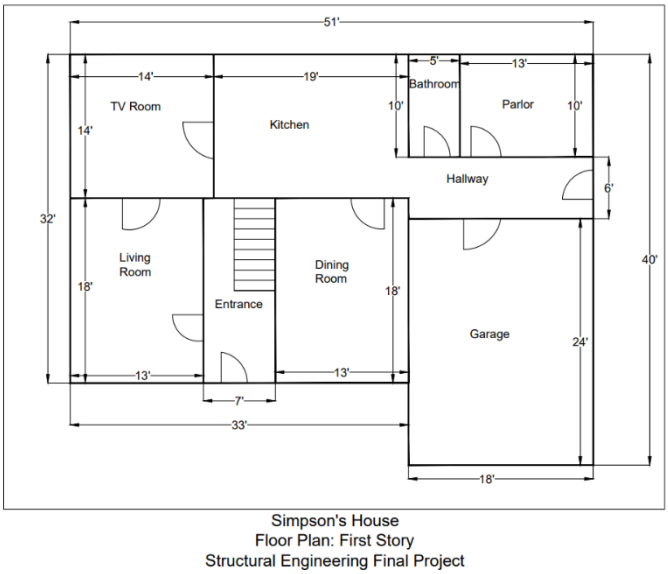
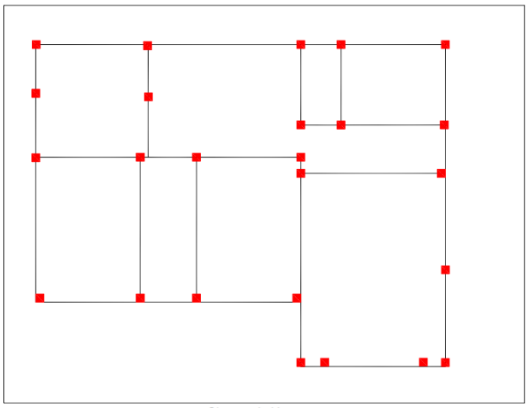
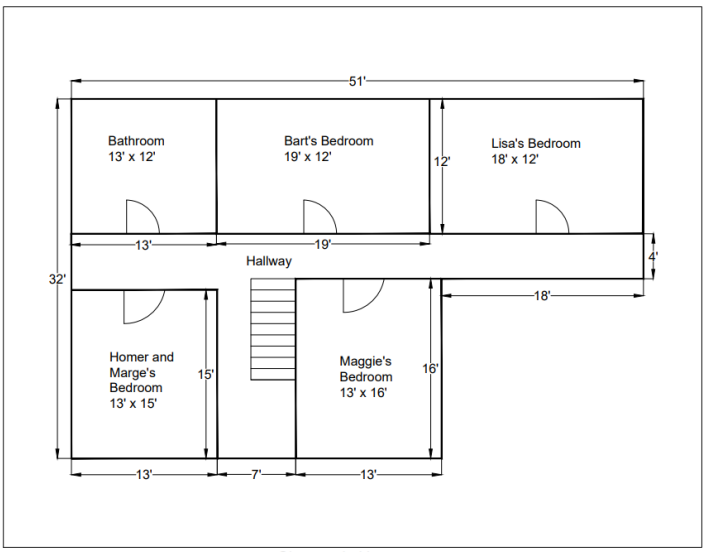


Figure 1. First Story Floor Plan.



Simpson's House
Column Plan: First Story
Structural Engineering Final Project

Figure 2. First Story Column Plan.



Simpson's House
Floor Plan: Second Story
Structural Engineering Final Project

Figure 3. Second Story Floor Plan.

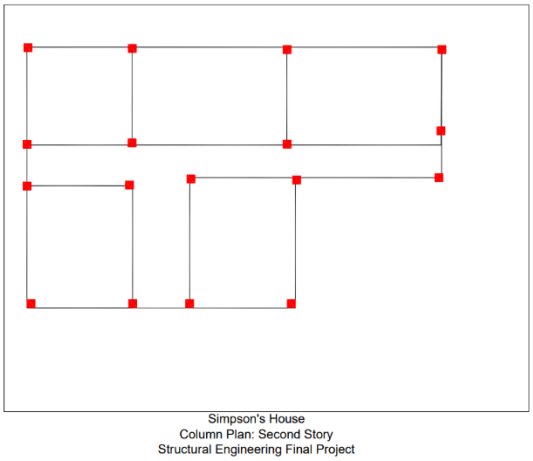


Figure 4. Second Story Column Plan.

Risa Model

The AutoCAD floor plan gives an outline to creating a 3D model of The Simpson's home using RISA 3D. The foundation of this structure is 3000NW 12x14" concrete columns that are eight feet high. These columns are based at the corners of the rooms based off the floor plan. W14x43 Hot rolled steel girders are connected to the concrete columns on the first floor of the structure and are also connected to the W8x10 hot rolled steel columns on the second floor of the structure. These girders will help support the weight from the structure and live loads. 10x12" DF wooden beams are connected to the steel girders spaced two feet apart. The truss of the structure is made from 8x8 DF wooden truss cords, 4x4 truss DF wooden webs, 2x2 and 2x3 DF wooden purlins, and an 8.5x9.625 glulam beam at the end of the truss. The rendered model of the structure can be found in figure 5.

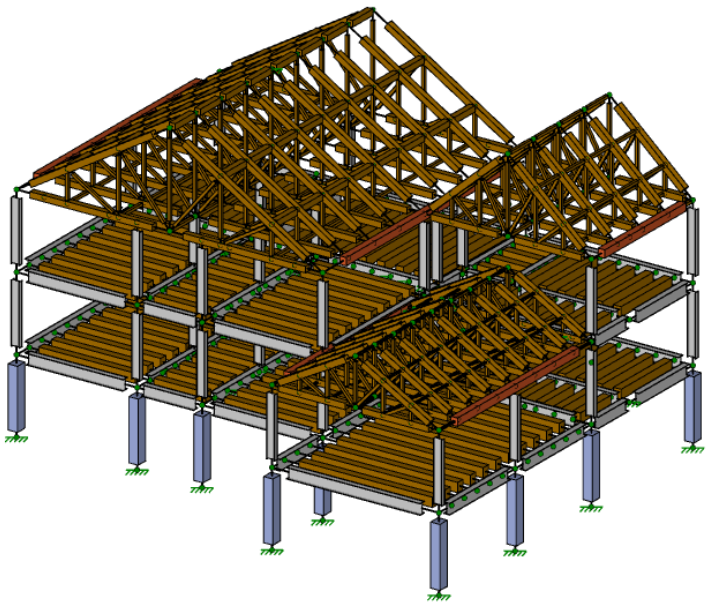


Figure 5. Rendered House Model from RISA.

Material Structural Analysis

2. Concrete Columns

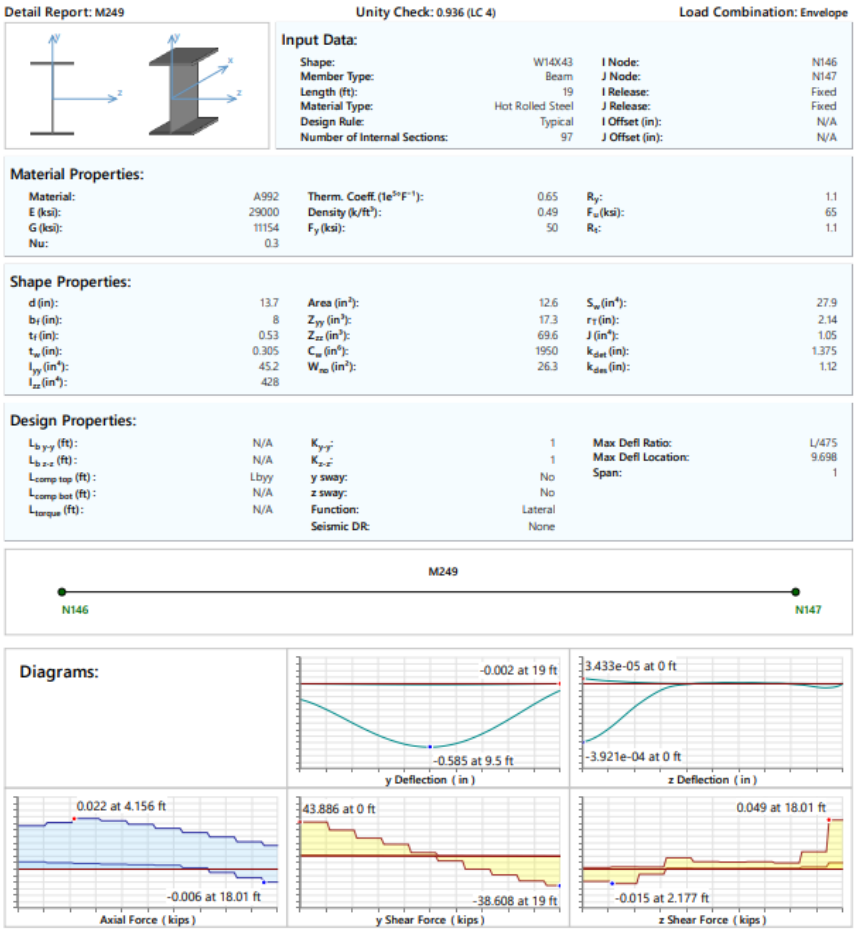
Concrete columns are used to act as the foundation of the structure. These concrete columns hold the dead load of the entire structure as well as the live loads that are applied to the structure as well. This concrete column is in the center of the structure. Columns on the corner of the structure have do not have a shear force in the y or z direction. The concrete structure has some deflection and shear force in the y and z direction. This concrete column also has a moment in the y and z direction (figure 6).

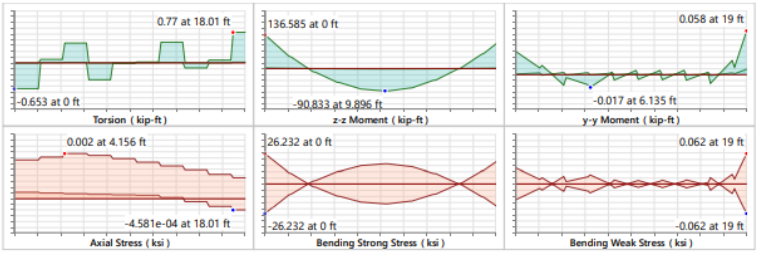
Limit State	Gov. LC	Required	Available	Unity Check	Result
Applied Loading Bending/Axial					
Flexural Reinforcement	8	1.68 in^2	1.767 in^2	-	Pass
Axial Capacity	8	39.82 k	275.56 k	0.145	Pass
Bending Unity Check	8	0.576 k-ft	3.985 k-ft	0.145	Pass
Y Shear Design Strength	5	0.547 k	29.299 k	0.019	Pass
Z Shear Design Strength	3	0.184 k	32.778 k	0.006	Pass
Threshold Torsion		0.002 k-ft	1.914 k-ft	1	Pass
Span Information					
Rebar Detailing					

Figure 6. Concrete Column Detailed from RISA

3. Steel Girders

Steel girders are used to support the wooden beams of the house. The shape of the steel girders is wide flange. This steel girder is in the center of the structure. The diagram shows some deflection, shear force, and moment in the y and z direction (Figure 7).





AISC 15th (360-16): ASD Code Check

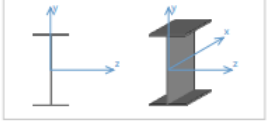
Limit State	Gov. LC	Required	Available	Unity Check	Result
Applied Loading - Bending/Axial	4	-	-	-	-
Applied Loading - Shear + Torsion	4	-	-	-	-
Axial Tension Analysis	4	0.000 k	377.246 k	-	-
Axial Compression Analysis	4	0.006 k	130.692 k	-	-
Flexural Analysis (Strong Axis)	4	136.585 k-ft	173.653 k-ft	-	-
Flexural Analysis (Weak Axis)	4	6.45 k-ft	43.164 k-ft	-	-
Shear Analysis (Major Axis y)	4	48.172 k	83.57 k	0.576	Pass
Shear Analysis (Minor Axis z)	4	10.202 k	152.335 k	0.067	Pass
Bending & Axial Interaction Check (UC Bending Max)	4	-	-	0.936	Pass

Figure 7. Steel Girder Detailed Report from RISA.

4. Steel Columns

Steel columns are used to support the first story, second story, and truss of the structure. The shape of the steel columns is wide flange. This steel column is located on the outside of the structure. The diagram shows some deflection, shear force, and moment in the y and z direction (Figure 8).

Detail Report: M735 **Unity Check:** 0.473 (LC 4) **Load Combination:** Envelope



Input Data:

Shape:	W8X10	I Node:	N436
Member Type:	Column	J Node:	N160
Length (ft):	8	I Release:	Fixed
Material Type:	Hot Rolled Steel	J Release:	Fixed
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	97	J Offset (in):	N/A

Material Properties:

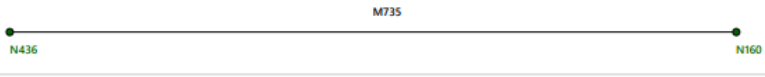
Material:	A992	Therm. Coeff. ($1e^{-5}F^{-1}$):	0.65	R_y:	1.1
E (ksi):	29000	Density (k/ft^3):	0.49	F_u (ksi):	65
G (ksi):	11154	F_y (ksi):	50	R_t:	1.1
Nu:	0.3				

Shape Properties:

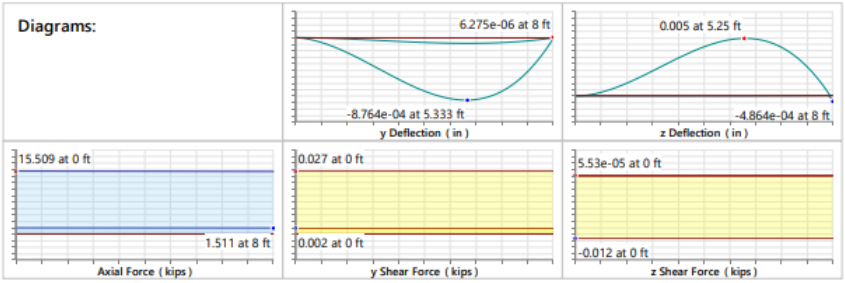
d (in):	7.89	Area (in^2):	2.96	S_w (in^4):	1.53
b_f (in):	3.94	Z_{yy} (in^3):	1.66	r_T (in):	1
t_f (in):	0.205	Z_{zz} (in^3):	8.87	J (in^4):	0.043
t_w (in):	0.17	C_w (in^6):	30.9	k_{det} (in):	0.688
I_{yy} (in^4):	2.09	W_{no} (in^2):	7.57	k_{des} (in):	0.505
I_{zz} (in^4):	30.8				

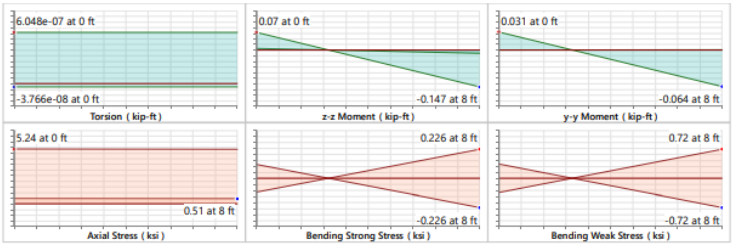
Design Properties:

$L_{b\,y\text{-}y}$ (ft):	N/A	$K_{y\text{-}y}$:	1	Max Defl Ratio:	L/0
$L_{b\,z\text{-}z}$ (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:





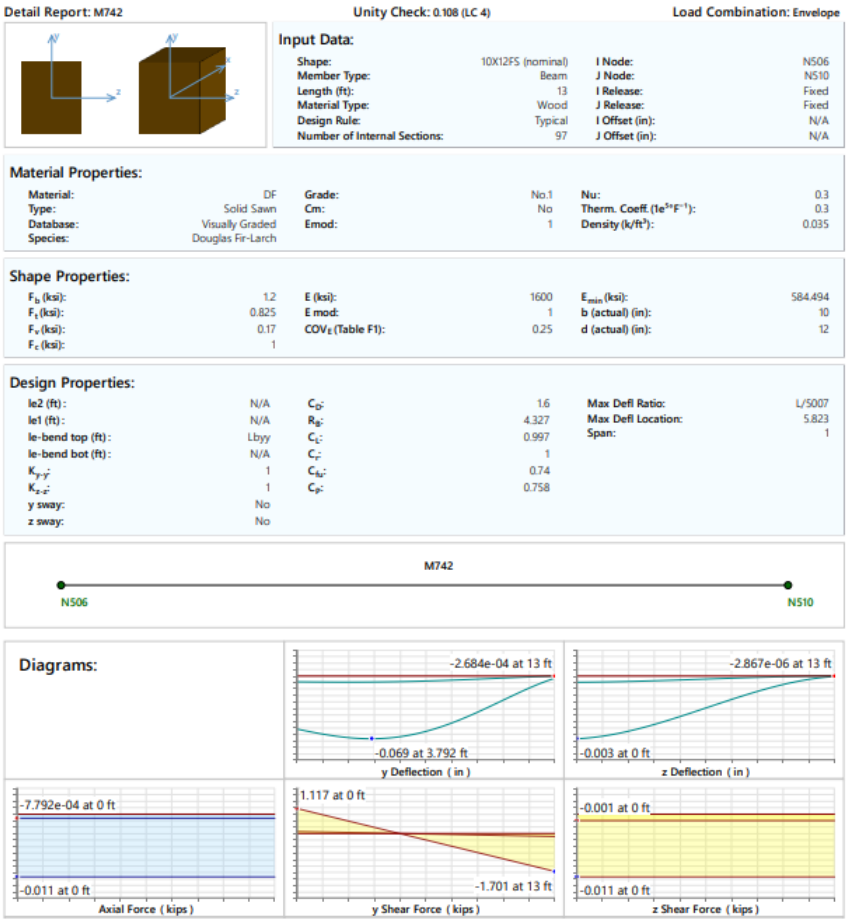
AISC 15th (360-16): ASD Code Check

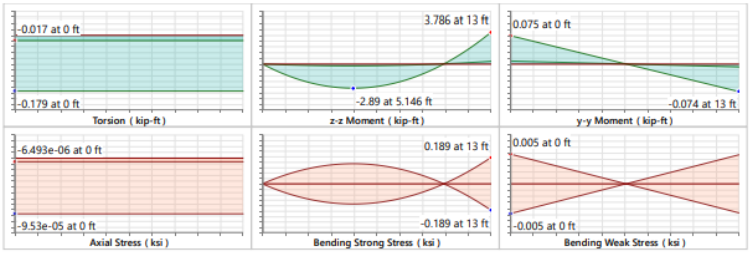
Limit State	Gov. LC	Required	Available	Unity Check	Result
Applied Loading - Bending/Axial	4	-	-	-	-
Applied Loading - Shear + Torsion	4	-	-	-	-
Axial Tension Analysis	4	0.000 k	88.623 k	-	-
Axial Compression Analysis	4	15.429 k	34.087 k	-	-
Flexural Analysis (Strong Axis)	4	0.147 k-ft	21.87 k-ft	-	-
Flexural Analysis (Weak Axis)	4	0.064 k-ft	4.071 k-ft	-	-
Shear Analysis (Major Axis y)	4	0.027 k	26.826 k	0.001	Pass
Shear Analysis (Minor Axis z)	4	0.012 k	29.019 k	0.000	Pass
Bending & Axial Interaction Check (UC Bending Max)	4	-	-	0.473	Pass

Figure 8. Steel Column Detailed Report from RISA

5. Wooden Beams

The wooden beams of the structure are connected to the steel girders on the first and second story. The shape of the wooden beam is rectangular. This wooden beam is located on the second story toward the outer edge of the structure. The diagram shows some deflection, shear force, and moment in the y and z direction (Figure 9).





AWC NDS-18: ASD Code Check

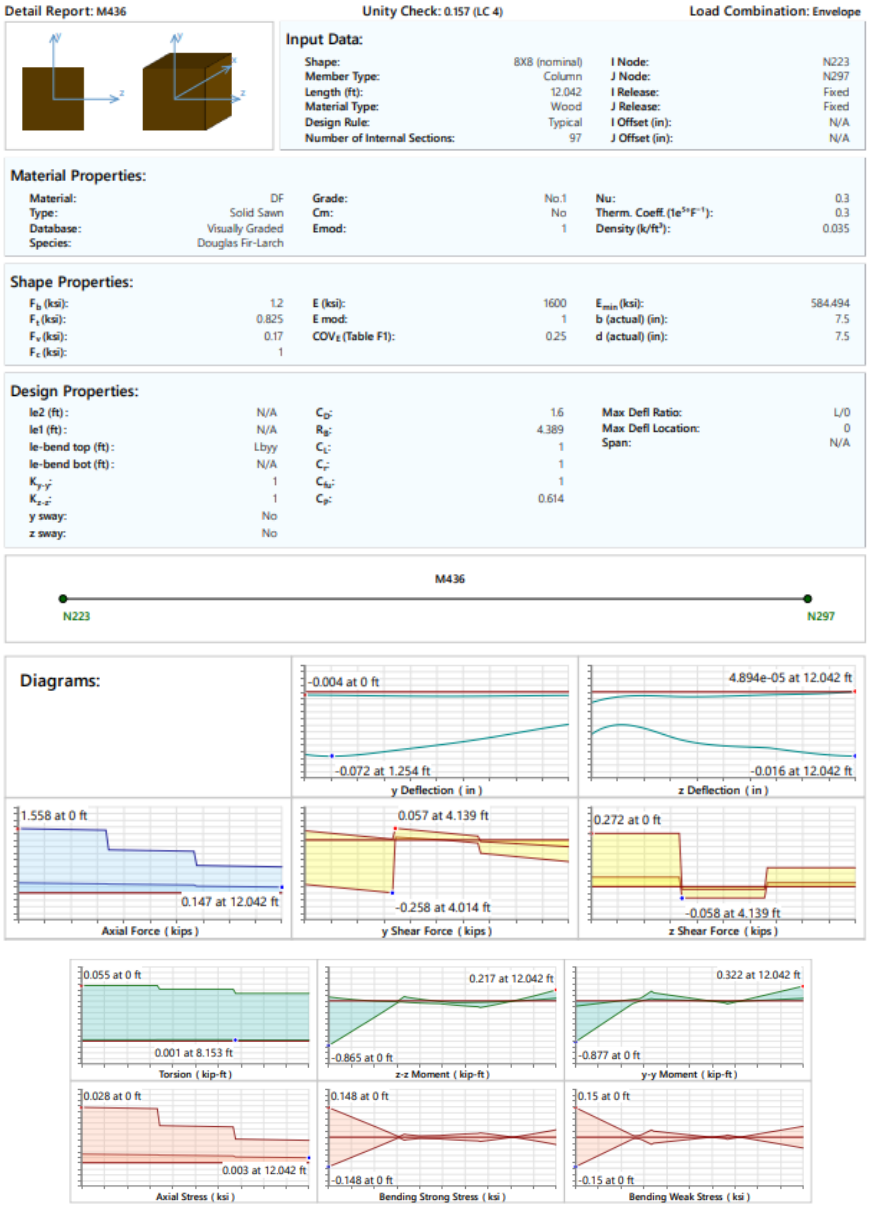
Limit State	Gov. LC	Required	Available	Unity Check	Result
Applied Loading - Bending/Axial	4	-	-	-	-
Applied Loading - Shear + Torsion	4	-	-	-	-
Axial Compression Analysis		0.000 ksi	1.213 ksi	-	-
Axial Tension Analysis		0.000 ksi	1.32 ksi	-	-
Flexural Analysis, Fb1'		0.189 ksi	1.915 ksi	-	-
Flexural Analysis, Fb2'		0.004 ksi	1.421 ksi	-	-
Bending & Axial Compression Analysis		-	-	0.102	Pass
Bending & Axial Tension Analysis		-	-	0.102	Pass
Shear Analysis		0.029 ksi	0.272 ksi	0.108	Pass

Figure 9. Wooden Beam Detailed Report from RISA

6. Wooden Truss

The truss of the structure is made from 8x8 DF wooden truss cord, 4x4 DF wooden truss web, 2x2 and 2x3 truss purlins, and 8.5x9.625 wooden glulam beam. Majority of the live load is applied to the roof of the structure. There is a roof live load that is applied to the truss to represent temporary load on the roof. For example, rain, snow, construction workers, etc. This load was applied in the -0.125k/ft in the y direction. The detailed report of each member is in figures 10-13.

a. Wooden Truss Cord

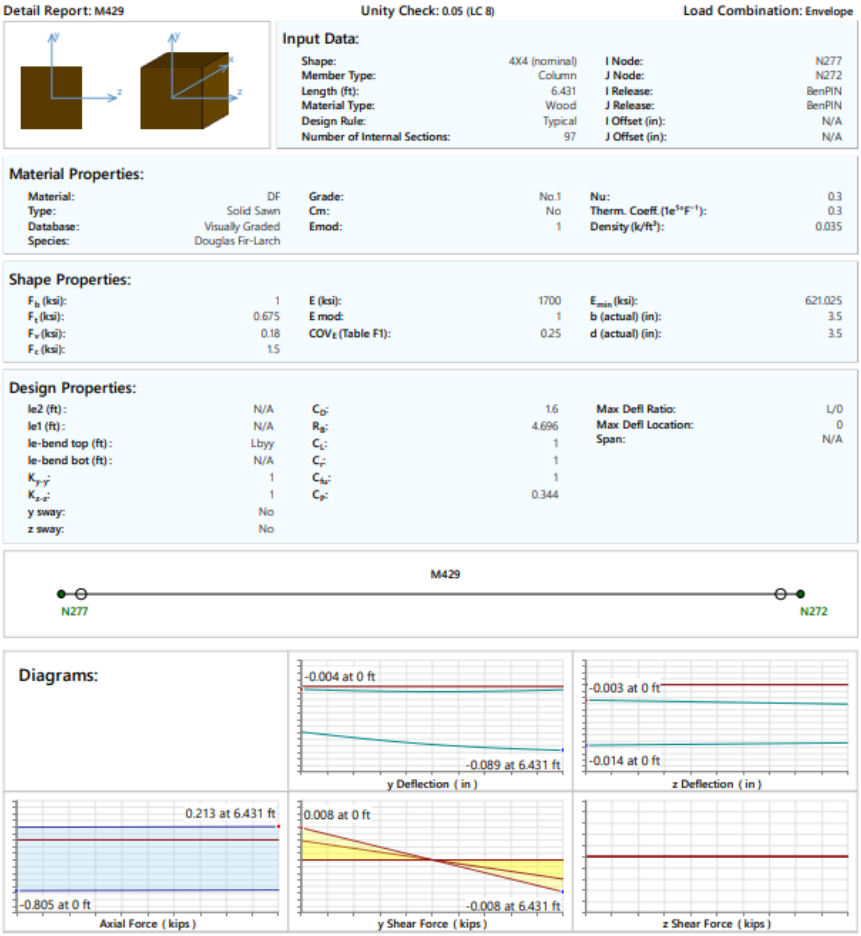


AWC NDS-18: ASD Code Check

Limit State	Gov. LC	Required	Available	Unity Check	Result
Applied Loading - Bending/Axial	4	-	-	-	-
Applied Loading - Shear + Torsion	4	-	-	-	-
Axial Compression Analysis		0.028 ksi	0.982 ksi	-	-
Axial Tension Analysis		0.000 ksi	1.32 ksi	-	-
Flexural Analysis, Fb1'		0.144 ksi	1.92 ksi	-	-
Flexural Analysis, Fb2'		0.15 ksi	1.92 ksi	-	-
Bending & Axial Compression Analysis		-	-	0.157	Pass
Bending & Axial Tension Analysis		-	-	0.153	Pass
Shear Analysis		0.015 ksi	0.272 ksi	0.054	Pass

Figure 10. Wooden Truss Cord Detailed Report from RISA

b. Wooden Truss Webs



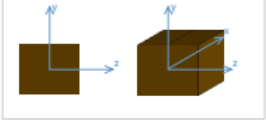
AWC NDS-18: ASD Code Check

Limit State	Gov. LC	Required	Available	Unity Check	Result
Applied Loading - Bending/Axial	8	-	-	-	-
Applied Loading - Shear + Torsion	2	-	-	-	-
Axial Compression Analysis		0.000 ksi	0.95 ksi	-	-
Axial Tension Analysis		-0.065 ksi	1.62 ksi	-	-
Flexural Analysis, Fb1'		0.022 ksi	2.4 ksi	-	-
Flexural Analysis, Fb2'		0.000 ksi	2.4 ksi	-	-
Bending & Axial Compression Analysis		-	-	0.05	Pass
Bending & Axial Tension Analysis		-	-	0.05	Pass
Shear Analysis		0.005 ksi	0.288 ksi	0.018	Pass

Figure 11. Wooden Truss Web Detailed Report from RISA

c. Wooden Truss Purlins

Detail Report: M78 | **Unity Check:** 0.21 (LC 4) | **Load Combination:** Envelope



Input Data:

Shape:	2-2X3 (nominal)	I Node:	N69
Member Type:	Beam	J Node:	N81
Length (ft):	3	I Release:	BenPIN
Material Type:	Wood	J Release:	BenPIN
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	97	J Offset (in):	N/A

Material Properties:

Material:	DF	Grade:	No.1	Nu:	0.3
Type:	Solid Sawn	Cm:	No	Therm. Coeff. ($1e^{-5}F^{-1}$):	0.3
Database:	Visually Graded	Emod:	1	Density (k/ft^3):	0.035
Species:	Douglas Fir-Larch				

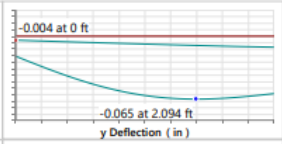
Shape Properties:

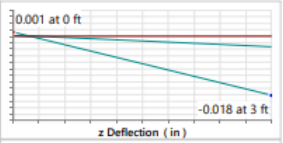
F_b (ksi):	1	E (ksi):	1700	b (actual) (in):	3
F_t (ksi):	0.675	E mod:	1	d (actual) (in):	2.5
F_v (ksi):	0.18	COV_E (Table F1):	0.25	# of Plies:	2
F_c (ksi):	1.5	E_{min} (ksi):	621.025	K_f:	0.6

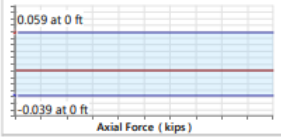
Design Properties:

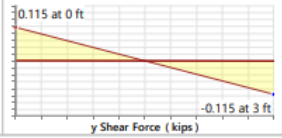
le2 (ft):	N/A	C_D:	1.6	Max Defl Ratio:	L/1707
le1 (ft):	N/A	R_B:	3.162	Max Defl Location:	1.5
le-bend top (ft):	Lbyy	C_L:	0.998	Span:	1
le-bend bot (ft):	N/A	C_r:	1		
K_{y-y}:	1	C_{fu}:	1		
K_{z-z}:	1	C_p:	0.462		
y sway:	No	K_f:	0.6		
z sway:	No				

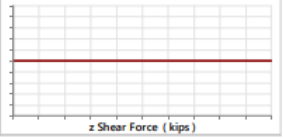
Diagrams:

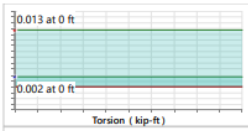


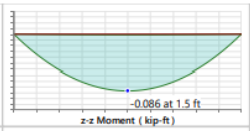


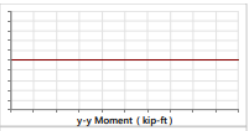


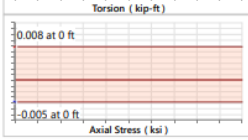


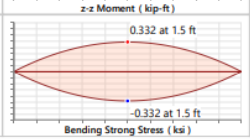


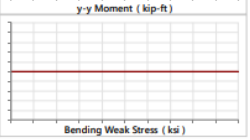












AWC NDS-18: ASD Code Check

Limit State	Gov. LC	Required	Available	Unity Check	Result
Applied Loading - Bending/Axial	4	-	-	-	-
Applied Loading - Shear + Torsion	4	-	-	-	-
Axial Compression Analysis		0.008 ksi	1.275 ksi	-	-
Axial Tension Analysis		0.000 ksi	1.62 ksi	-	-
Flexural Analysis, Fb1'		0.332 ksi	2.396 ksi	-	-
Flexural Analysis, Fb2'		0.000 ksi	2.4 ksi	-	-
Bending & Axial Compression Analysis		-	-	0.139	Pass
Bending & Axial Tension Analysis		-	-	0.139	Pass
Shear Analysis		0.06 ksi	0.288 ksi	0.21	Pass

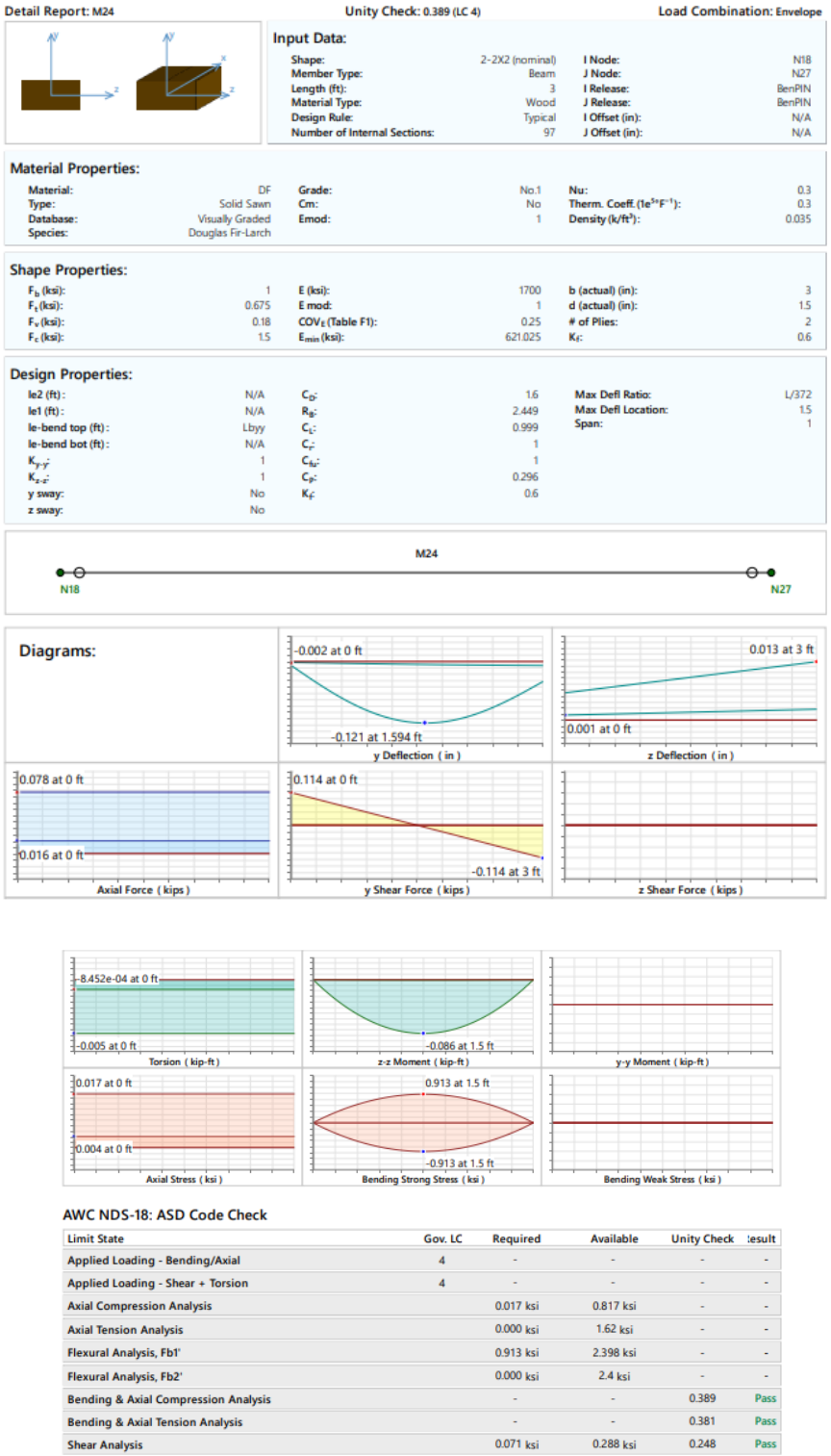


Figure 12. Wooden Purlin Detailed Report from RISA

d. Wooden Glulam Beams

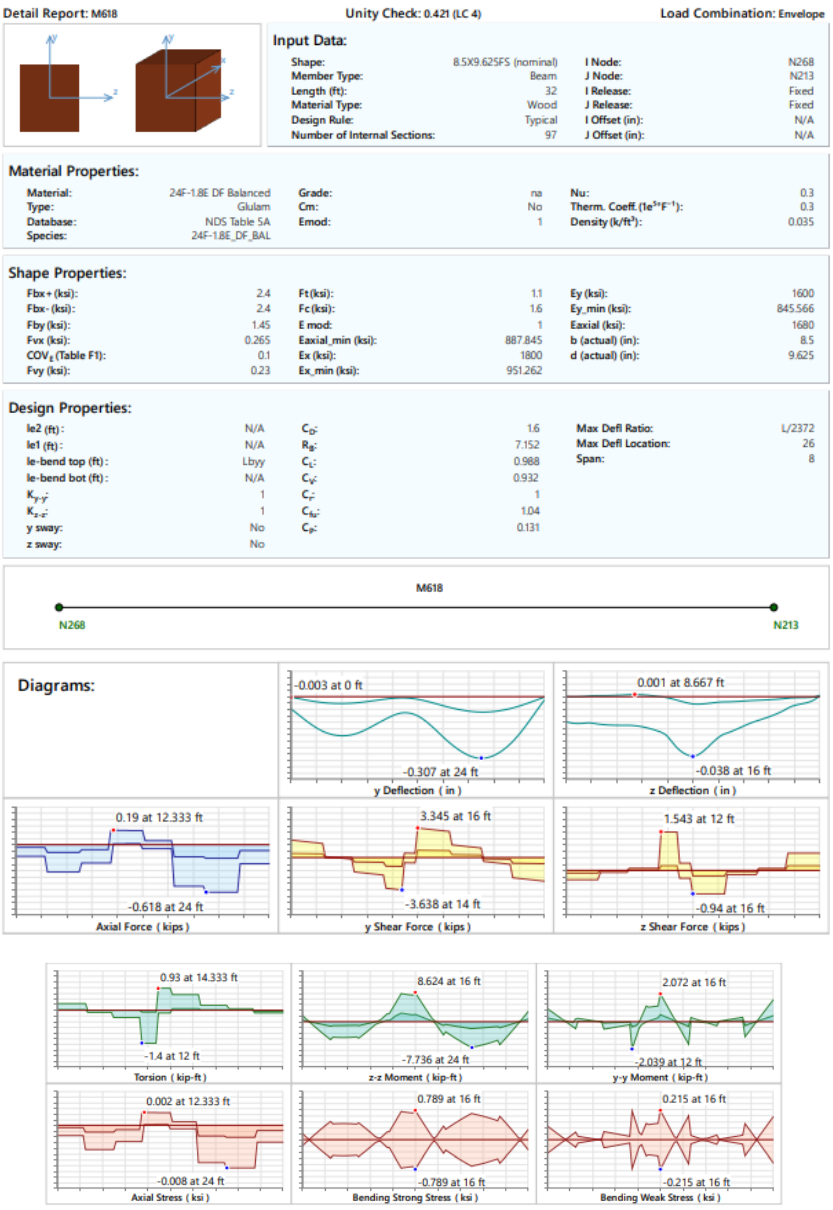


Figure 13. Glulam Beam Detailed Report from RISA

Cost Analysis

This structure was constructed using concrete, hot rolled steel, and wood. Information such as the number of pieces, total weight, and total length of the materials can be found under the material takeoff tab on RISA. Costs of wood materials can be found on Lowes's website, the cost of hot rolled steel materials can be found on Midwest Steel Supply website, and average cost of a ton of concrete was ranged between $117-$147. The total cost of the materials for the structure comes out to be $49,449.57 (Figure 14). This cost does not include the cost of labor to construct the structure.

Material	Size	Pieces	Length (ft)	Weight (K)	Price Per Piece	Total Price
Hot Rolled Steel						
A992	W8x10	39	312	9.385	98.19	3829.41
A992	W14x43	56	649	19.544	649.5	36372
Total		95	961	28.929		40201.41
Wood						
24F-1.8E DF Balanced Glulam	8.5x9.625FS	6	144	2.864	100.71	604.26
DF	10x12	125	1402	87.238	24.95	3118.75
DF	2-2x2	88	264	0.289	5.58	491.04
DF	2-2x3	8	24	0.044	3.15	25.2
DF	4x4	290	1372.2	4.086	9.98	2894.2
DF	8x8	131	1351.7	18.481	14.65	1919.15
Total		648	4557.9	113.001		9052.6
Concrete			Volume (yds^3)			
Conc3000NW	CRECT12x14	17	5.9	23.007	117	195.56
		17	5.9	23.007	117	195.56
Total Material Cost						49449.57

Figure 14. Cost Analysis

Conclusion

The objective of the project was to design a floor plan using AutoCAD to use to design a structure in RISA 3D using wood, hot rolled steel, and concrete. The process of designing the floor plan and 3D model took a lot of trial and error, as well as research and calculations. In the end, the structure was able to stay standing based off ASD codes. RISA gives detailed analysis of each member and node in the structure, which was very helpful during the design process. Now I have more experience in RISA 3D and AutoCAD because of this project.

References

Cost Analysis:

Hot Rolled-Steel beam prices: https://www.midweststeelsupply.com/store/hotrollsteelbeam

Wood members: https://www.lowes.com/

Concrete members: https://homeguide.com/costs/concrete-prices