

Structural Design and Analysis

PRESENTED BY: C.T

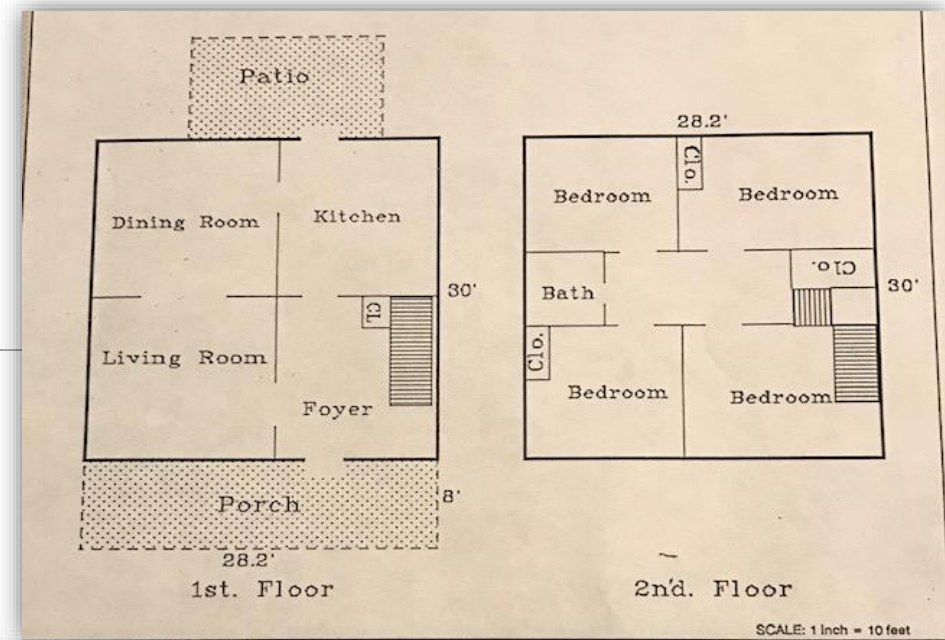
Introduction

- The assignment given was to create a floor plan and 3D model of a structure
- The structure built requires materials such as steel, wood, and concrete



Dimensions

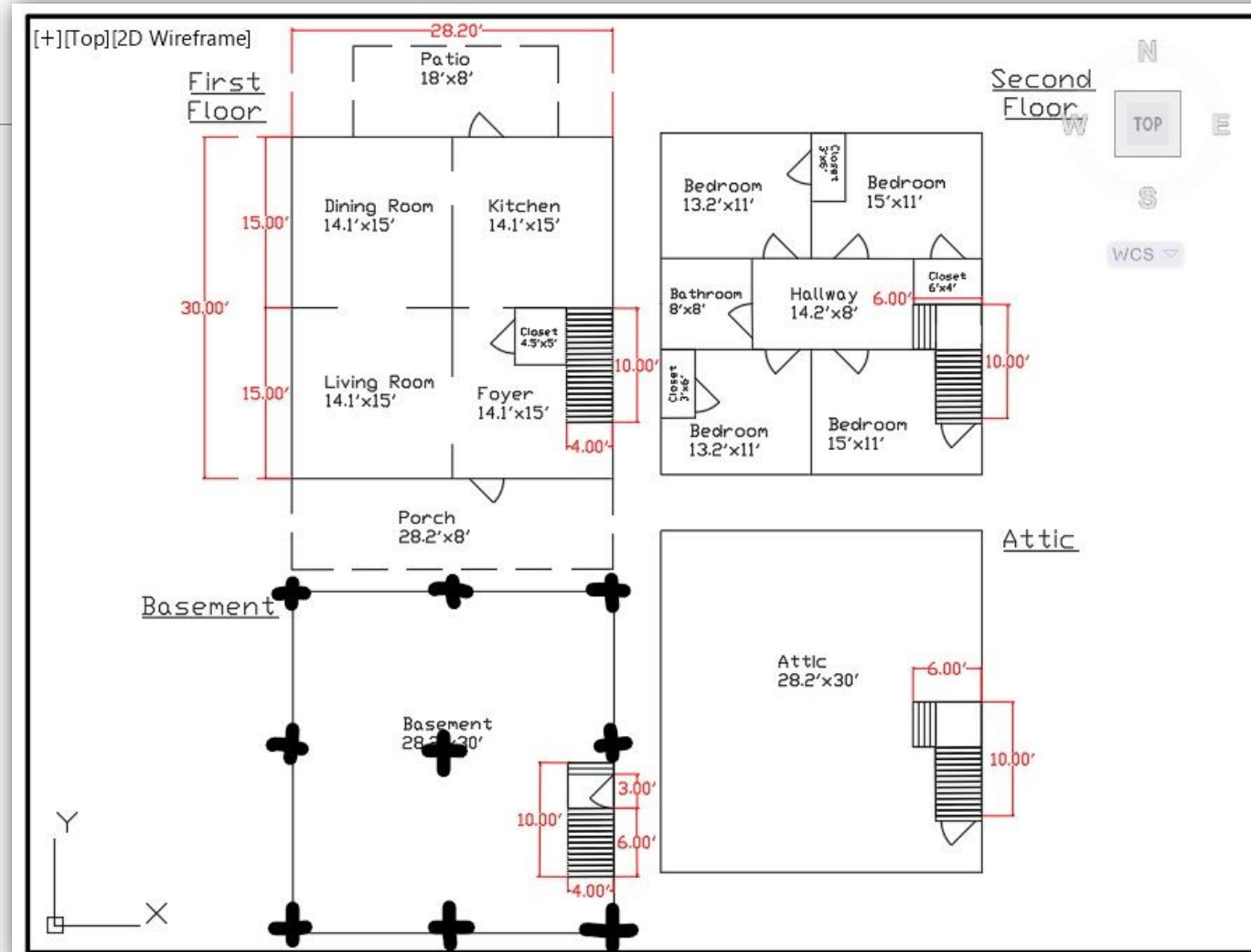
- I found measurements of the layout of my house and its surface area [sq. ft.]
- House consists of:
 - 4 bedrooms
 - 1 bathroom
 - Kitchen
 - Living Room
 - Dining Room
 - Foyer
 - Attic
 - Basement
 - 4 Closets



AREA CALCULATIONS SUMMARY				LIVING AREA CALCULATIONS			
Area	Name of Area	Size	Totals	Breakdown			Subtotals
GLA1	First Floor	846.00	846.00	28.20	X	30.00	846.00
GLA2	Second Floor	846.00	846.00	0.65	X	0.10	0.07
POR	Porch	225.60		28.20	X	30.00	846.00
	Porch	160.00	385.60	0.65	X	0.10	0.07
TOTAL LIVABLE (rounded)			1692				1692

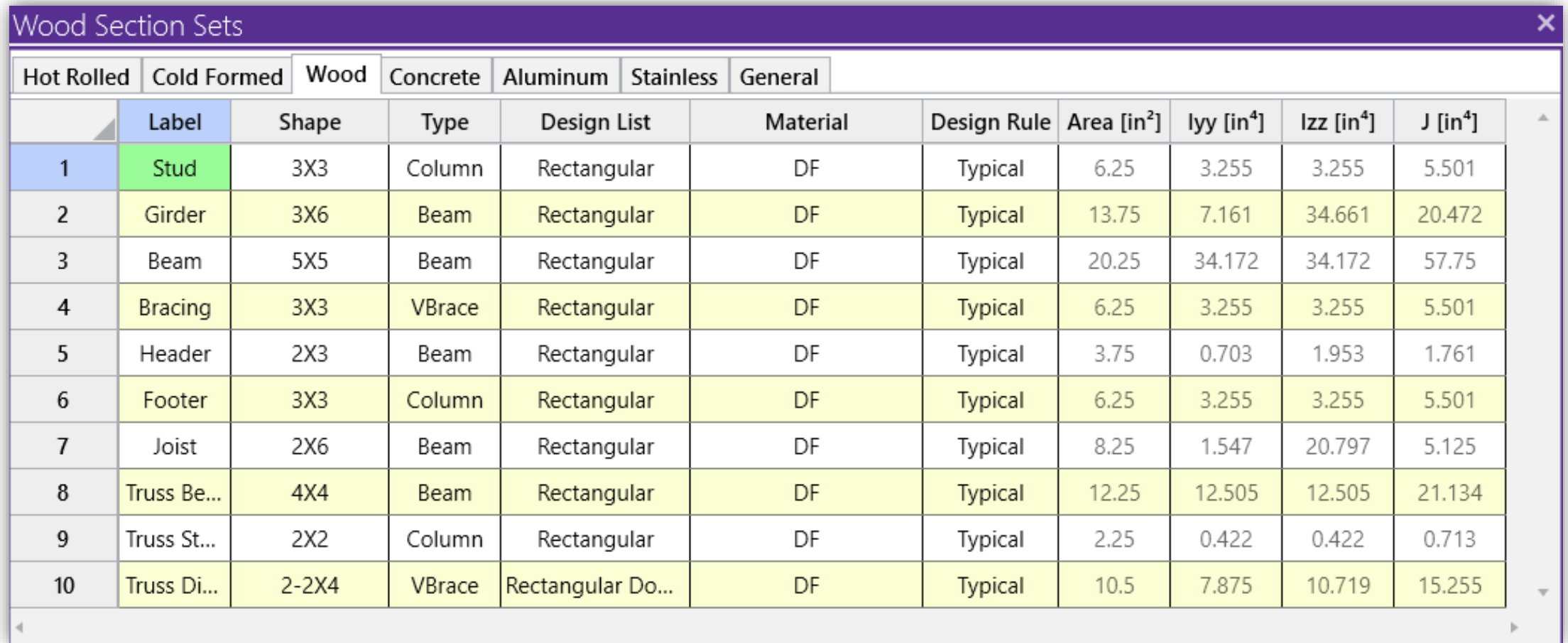
Floor Plan

- Using floor layout of house, I created a detailed floor plan using AutoCAD
- Allows me to create a more accurate 3D model on RISA
- Columns specifically located at corners, center edges, and center of house



Modeling

- Defined section sets
 - Selected choice of material, shape, type, etc.

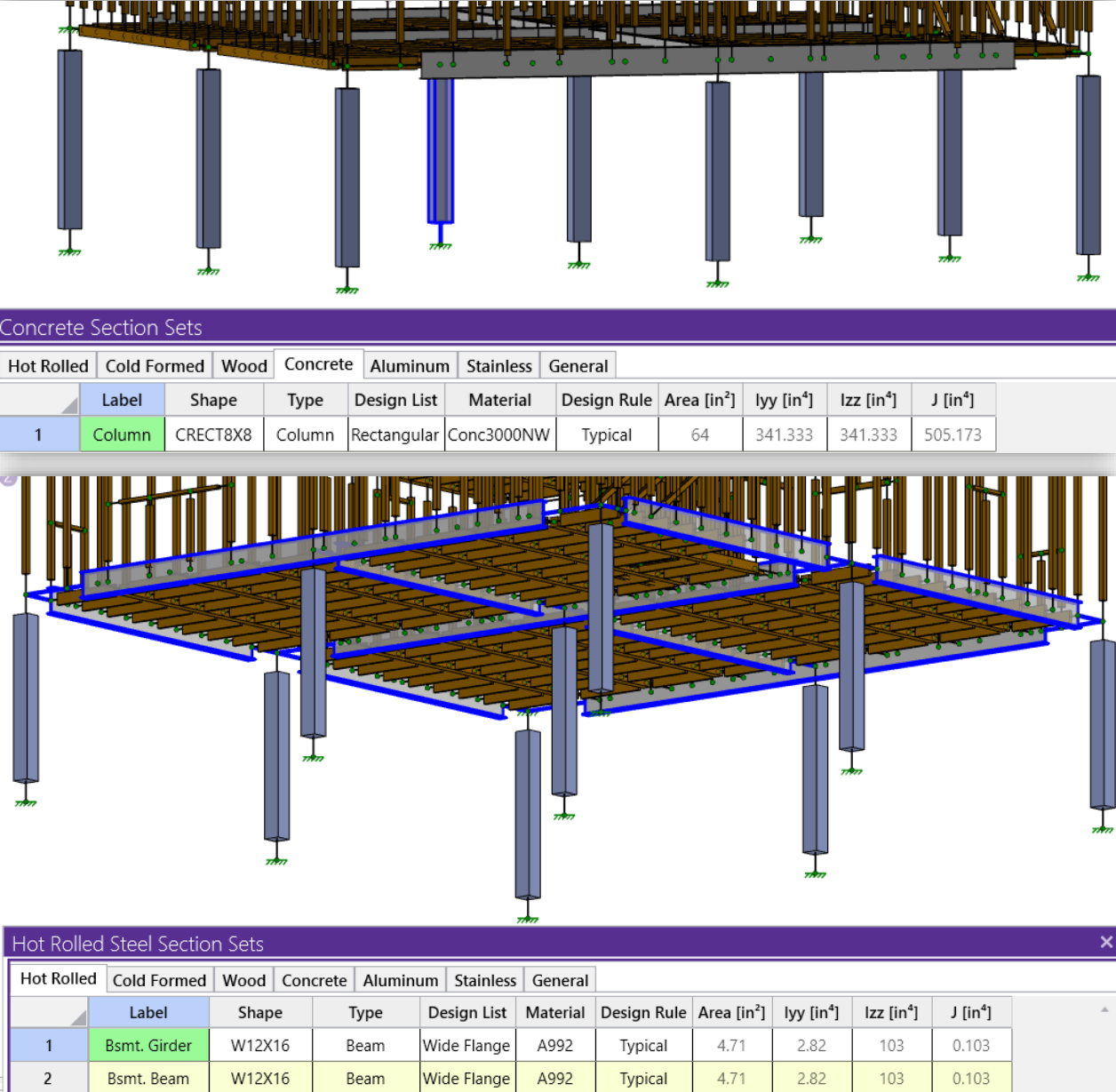


The screenshot shows a software window titled "Wood Section Sets" with a close button (X) in the top right corner. The window contains a table with 11 columns and 11 rows. The columns are: Label, Shape, Type, Design List, Material, Design Rule, Area [in²], I_{yy} [in⁴], I_{zz} [in⁴], and J [in⁴]. The rows are numbered 1 through 10. The "Wood" tab is selected, and the "Hot Rolled" sub-tab is active. The table lists various wood section types such as Stud, Girder, Beam, Bracing, Header, Footer, Joist, Truss Be..., Truss St..., and Truss Di... with their respective properties.

	Hot Rolled	Cold Formed	Wood	Concrete	Aluminum	Stainless	General				
	Label	Shape	Type	Design List	Material	Design Rule	Area [in ²]	I _{yy} [in ⁴]	I _{zz} [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	

Modeling

- Created the basement support columns (fixed boundary conditions)
- Next, created the main first-floor girders and beams (pinned on sides)
- After, inserted first-floor beams and floor joist between beams (pinned on sides)



The screenshot displays a structural modeling software interface. The top portion shows a 3D model of a building's basement and first floor. The basement support columns are highlighted in blue, and the first-floor girders and beams are highlighted in brown. The bottom portion of the screenshot shows two tables: 'Concrete Section Sets' and 'Hot Rolled Steel Section Sets'.

Concrete Section Sets

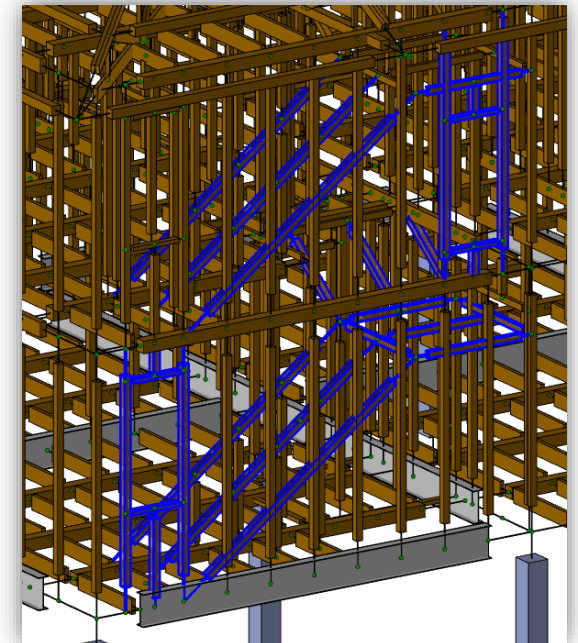
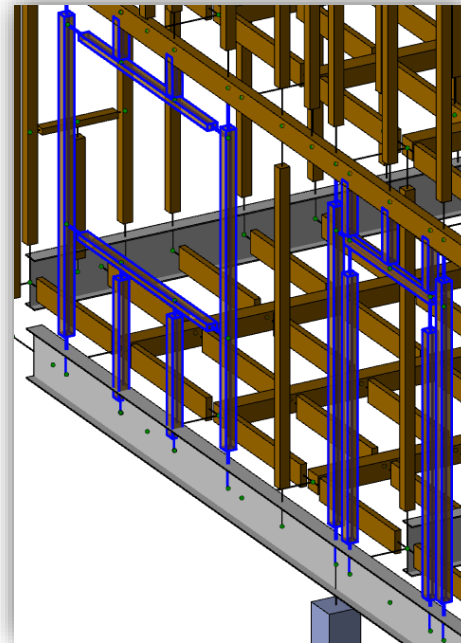
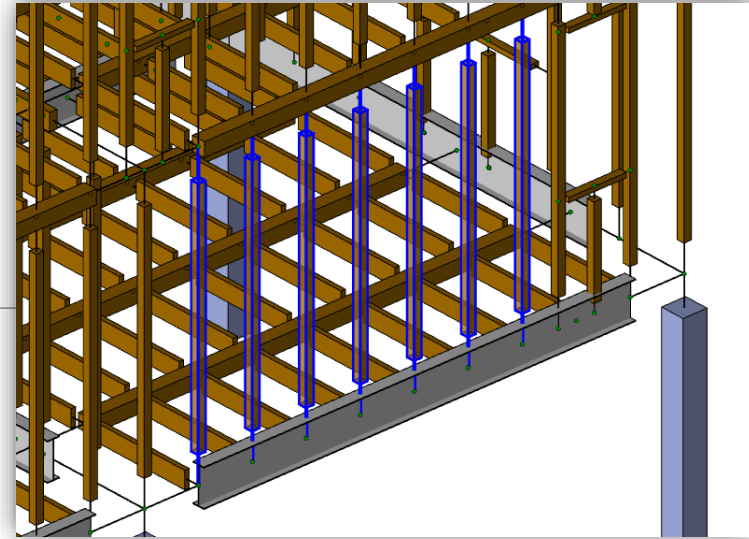
	Hot Rolled	Cold Formed	Wood	Concrete	Aluminum	Stainless	General				
	Label	Shape	Type	Design List	Material	Design Rule	Area [in ²]	Iyy [in ⁴]	Izz [in ⁴]	J [in ⁴]	
1	Column	CRECT8X8	Column	Rectangular	Conc3000NW	Typical	64	341.333	341.333	505.173	

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	

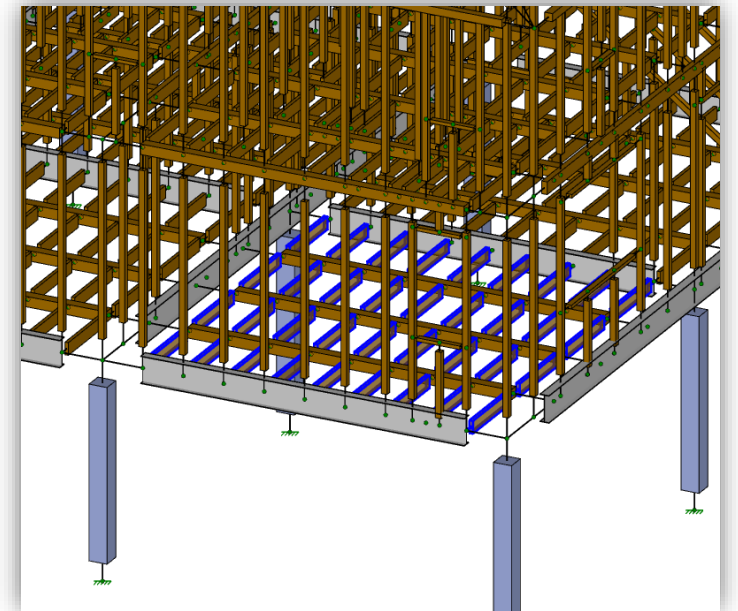
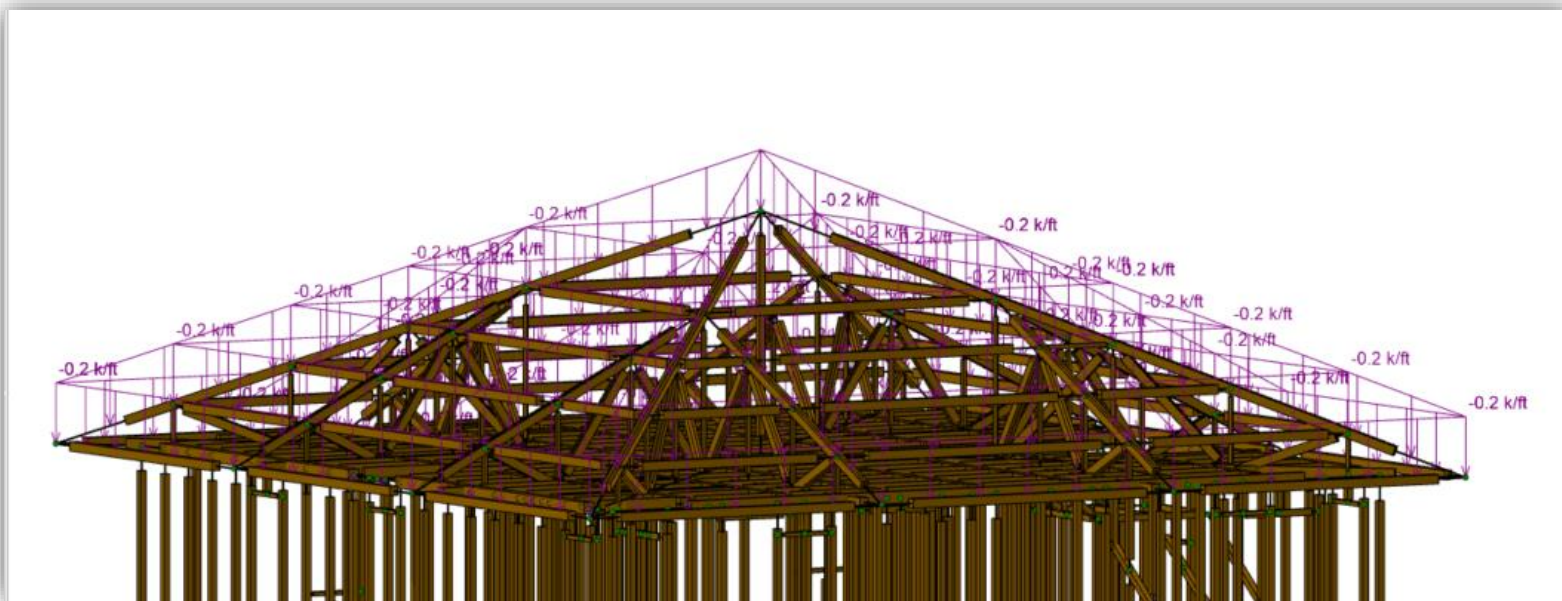
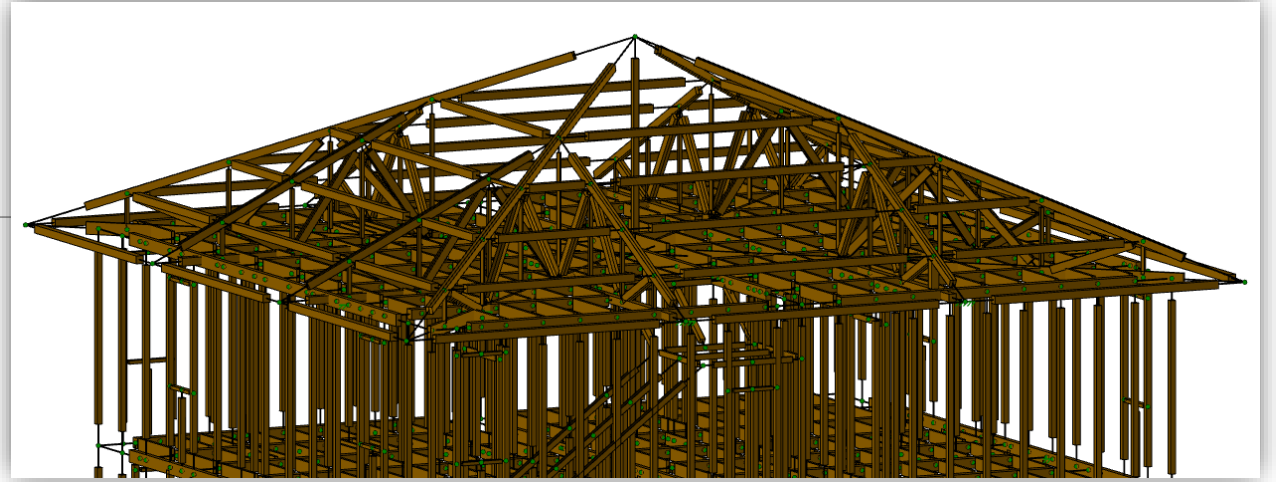
Modeling

- Designed external/internal walls using wooden studs
- Additionally, added door frames, window frames, and staircases
- After, inserted first-floor beams and floor joist between beams (pinned on sides)

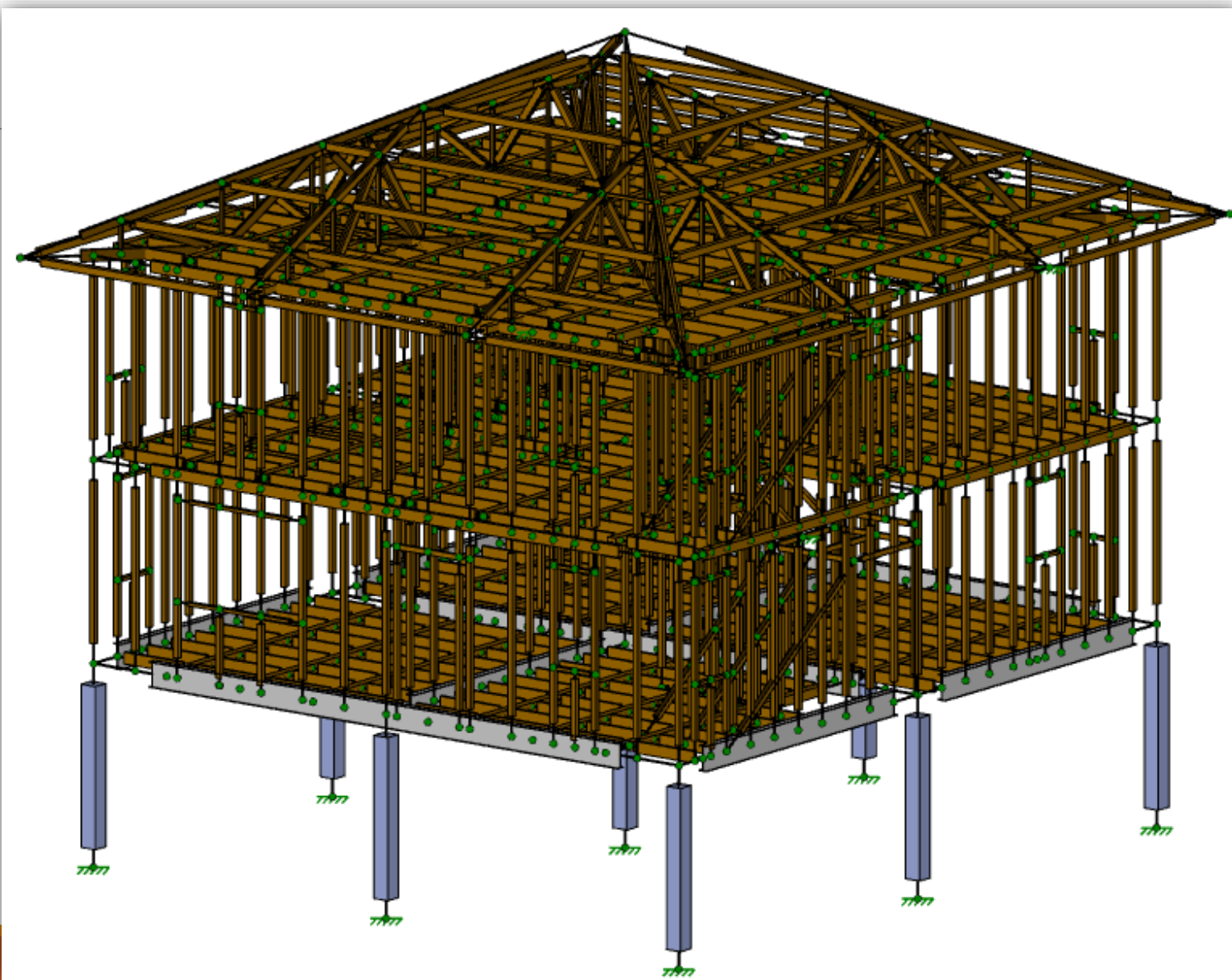


Modeling

- Designed roof trusses, floor joists between floor beams
- Roof trusses have applied live loads



Final Model



Structural Analysis

Concrete Columns:

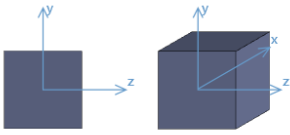
- Central Column
 - Supports most of structure
 - Reduces deflection from large steel girders
- Corner Column
 - Supports ends of steel girders and beams

HR Steel Beams:

- Steel Girders
 - Beams connected to girder throughout entire length
 - Wide flanged to prevent buckling from deflection
- Steel Beams
 - Connected to girder to support wooden floor beams/joists

Central Concrete Column:

Detail Report: M7 Unity Check: 0.025 (axial/bending) **Load Combination: Envelope**



Input Data:

Shape:	CRECT8X8	I Node:	N13
Member Type:	Column	J Node:	N14
Length (ft):	8	I Release:	BenPIN
Material Type:	Concrete	J Release:	BenPIN
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	97	J Offset (in):	N/A
Design Code:	ACI 318-19		

Material Properties:

Material:	Conc3000NW	Therm. Coeff. (1e ⁻⁵ *F ⁻¹):	0.6	Lambda:	1
E (ksi):	3156	Density (k/ft ³):	0.145	Flex Steel (ksi):	60
G (ksi):	1372	f'c (ksi):	3	Shear Steel (ksi):	60
Nu:	0.15				

Shape Properties:

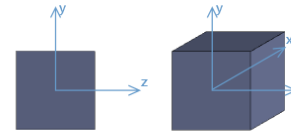
D (in):	8	W (in):	8
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Design Properties:

C _{m y-y} :	N/A	Concrete Stress Block:	Rectangular	Flex Rebar Set:	ASTM A615
C _{m z-z} :	N/A	Cracked Sections Used:	Yes	Shear Rebar Set:	ASTM A615
K _{y-y} :	1	Cracked "I" Factor:	0.7	Top Cover (in):	1.5
K _{z-z} :	1	Effective "I" (in ⁴):	238.933	Bottom Cover (in):	1.5
y sway:	No	Effective "I" (Service) (in ⁴):	341.675	Side Cover (in):	1.5
z sway:	No			Legs/Stirrup:	2

Corner Concrete Column:

Detail Report: M2 Unity Check: 0.009 (axial/bending) **Load Combination: Envelope**



Input Data:

Shape:	CRECT8X8	I Node:	N3
Member Type:	Column	J Node:	N4
Length (ft):	8	I Release:	BenPIN
Material Type:	Concrete	J Release:	Fixed
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	97	J Offset (in):	N/A
Design Code:	ACI 318-19		

Material Properties:

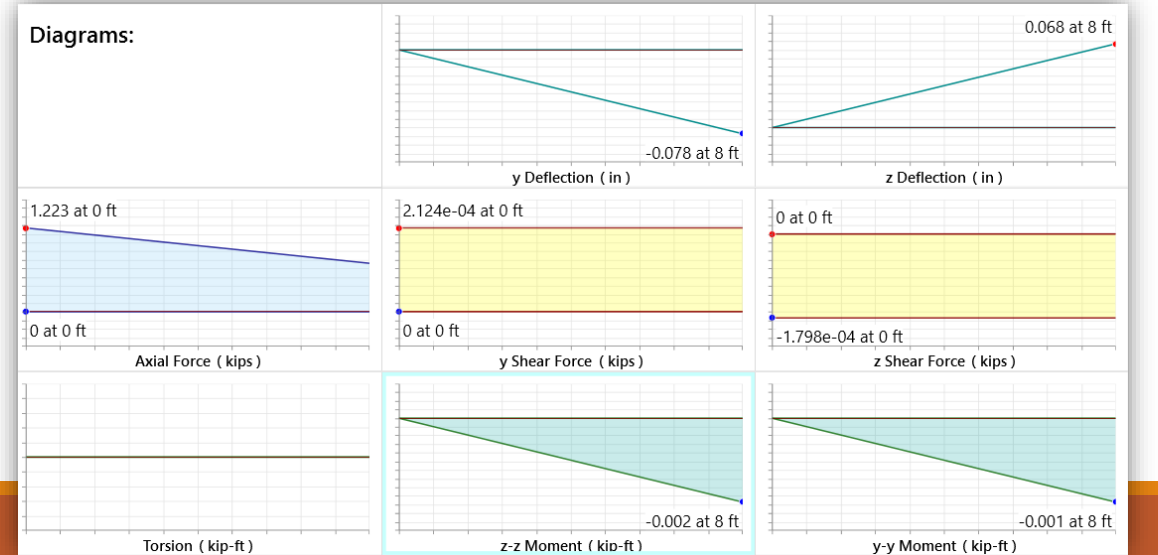
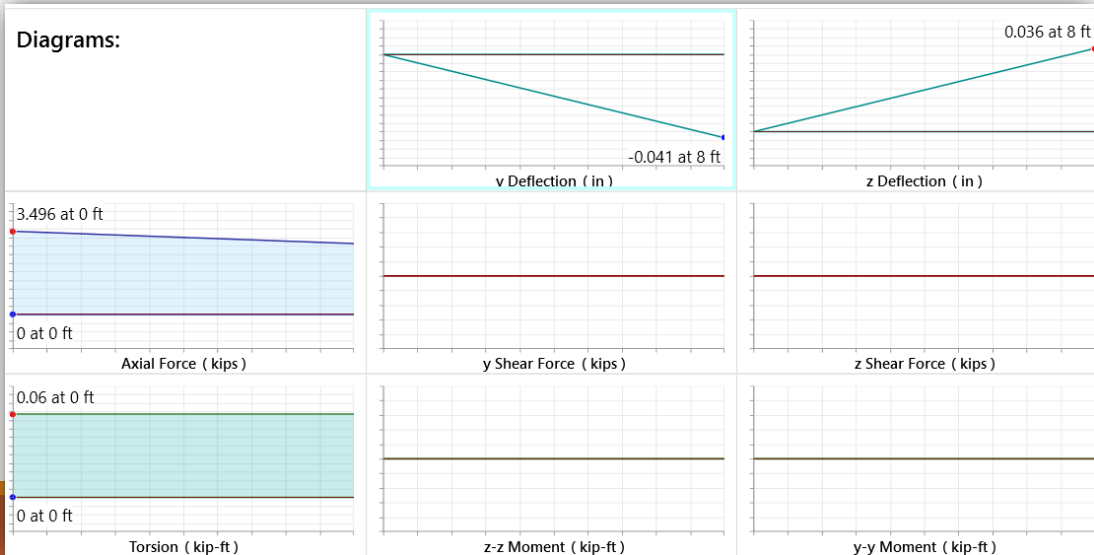
Material:	Conc3000NW	Therm. Coeff. (1e ⁻⁵ *F ⁻¹):	0.6	Lambda:	1
E (ksi):	3156	Density (k/ft ³):	0.145	Flex Steel (ksi):	60
G (ksi):	1372	f'c (ksi):	3	Shear Steel (ksi):	60
Nu:	0.15				

Shape Properties:

D (in):	8	W (in):	8
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Design Properties:

C _{m y-y} :	N/A	Concrete Stress Block:	Rectangular	Flex Rebar Set:	ASTM A615
C _{m z-z} :	N/A	Cracked Sections Used:	Yes	Shear Rebar Set:	ASTM A615
K _{y-y} :	1	Cracked "I" Factor:	0.7	Top Cover (in):	1.5
K _{z-z} :	1	Effective "I" (in ⁴):	238.933	Bottom Cover (in):	1.5
y sway:	No	Effective "I" (Service) (in ⁴):	341.675	Side Cover (in):	1.5
z sway:	No			Legs/Stirrup:	2



Central Steel Girder:

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:

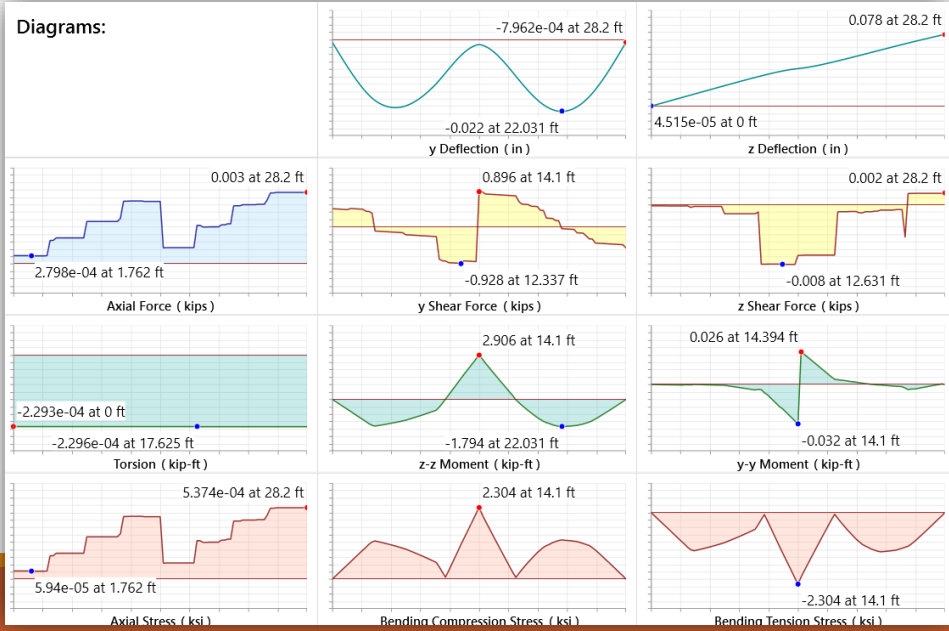
Material:	A992	Therm. Coeff. (1e ⁻⁶ F ⁻¹):	0.65	R _y :	1.1
E (ksi):	29000	Density (k/ft ³):	0.49	F _u (ksi):	65
G (ksi):	11154	F _y (ksi):	50	R _t :	1.1
Nu:	0.3				

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 _r (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 ³):	11.7	k _{des} (in):	0.565
I _{zz} (in ⁴):	103				

Design Properties:

L _{b y-y} (ft):	N/A	K _{y-y} :	1	Max Defl Ratio:	L/10000
L _{b z-z} (ft):	N/A	K _{z-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		



Steel Beam:

Detail Report: M12 **Unity Check: 0.238 (axial/bending)** **Load Combination: LC 1: DL+LL**

Input Data:

Shape:	W12X16	I Node:	N12
Member Type:	Beam	J Node:	N4
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:

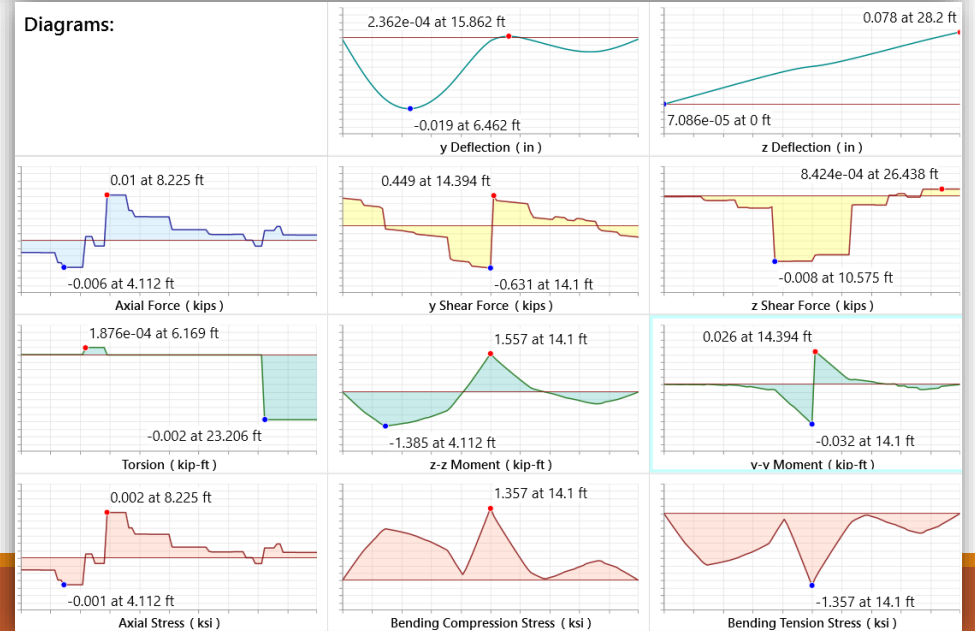
Material:	A992	Therm. Coeff. (1e ⁻⁶ F ⁻¹):	0.65	R _y :	1.1
E (ksi):	29000	Density (k/ft ³):	0.49	F _u (ksi):	65
G (ksi):	11154	F _y (ksi):	50	R _t :	1.1
Nu:	0.3				

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 _r (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 ³):	11.7	k _{des} (in):	0.565
I _{zz} (in ⁴):	103				

Design Properties:

L _{b y-y} (ft):	N/A	K _{y-y} :	1	Max Defl Ratio:	L/10000
L _{b z-z} (ft):	N/A	K _{z-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		



Structural Analysis

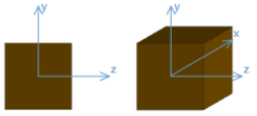
Wooden Studs:

- Central Wooden Stud
 - Supports most of structure
 - Reduces deflection from wooden girders on second floor
- Corner Wooden Stud
 - Supports ends of wooden girders and beams

Wooden Beams:

- Wooden Girders
 - Wooden beams connected to girder throughout entire length
 - Rectangular shape reduces deflection in vertical direction
- Wooden Beams
 - Connected to wooden girder to support wooden floor joists

Central Wood Stud:



Input Data:

Shape:	3X3 (nominal)	I Node:	N14
Member Type:	Column	J Node:	N109
Length (ft):	8	I Release:	BenPIN
Material Type:	Wood	J Release:	BenPIN
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	5	J Offset (in):	N/A

Material Properties:

Material:	DF	Grade:	No.1	Nu:	0.3
Type:	Solid Sawn	Cm:	No	Therm. Coeff. (1e ⁻⁶ F ⁻¹):	0.3
Database:	Visually Graded	Emod:	1	Density (k/ft ³):	0.035
Species:	Douglas Fir-Larch				

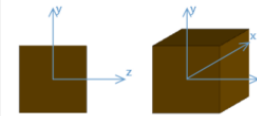
Shape Properties:

F _y (ksi):	1	E (ksi):	1700	E _{min} (ksi):	621.025
F ₁ (ksi):	0.675	E mod:	1	b (actual) (in):	2.5
F _v (ksi):	0.18	COV _E (Table F1):	0.25	d (actual) (in):	2.5
F _c (ksi):	1.5				

Design Properties:

le2 (ft):	N/A	C _D :	1	Max Defl Ratio:	L/10000
le1 (ft):	N/A	R _B :	6.197	Max Defl Location:	0
le-bend top (ft):	L _{byy}	C _L :	1	Span:	N/A
le-bend bot (ft):	N/A	C _r :	1		
K _{y-y} :	1	C _{t0} :	1		
K _{z-z} :	1	C _p :	0.192		
y sway:	No				
z sway:	No				

Corner Wood Stud:



Input Data:

Shape:	3X3 (nominal)	I Node:	N12
Member Type:	Column	J Node:	N92
Length (ft):	8	I Release:	BenPIN
Material Type:	Wood	J Release:	BenPIN
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	5	J Offset (in):	N/A

Material Properties:

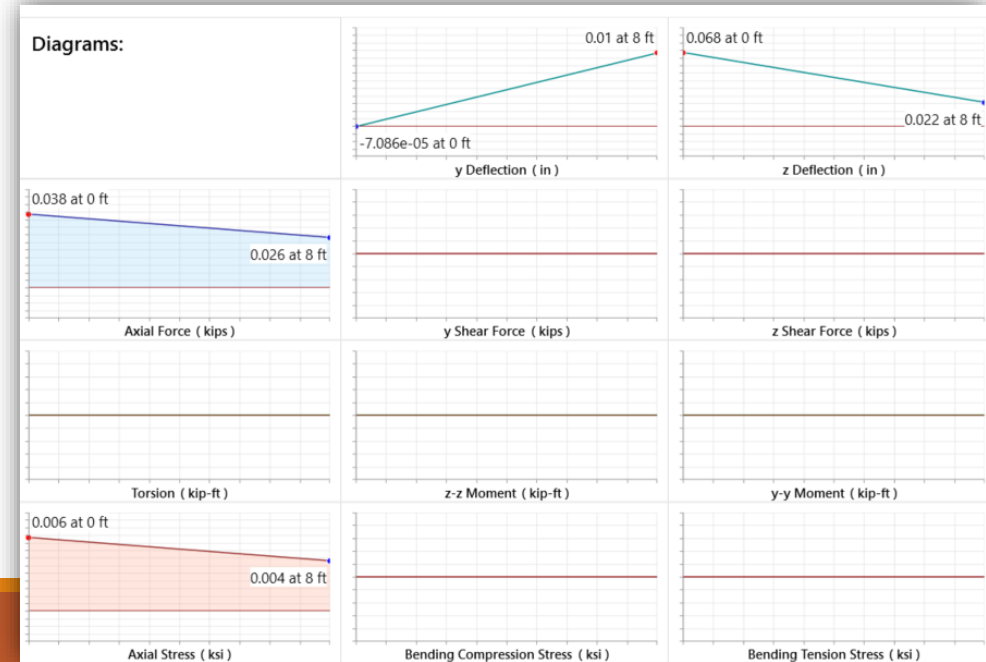
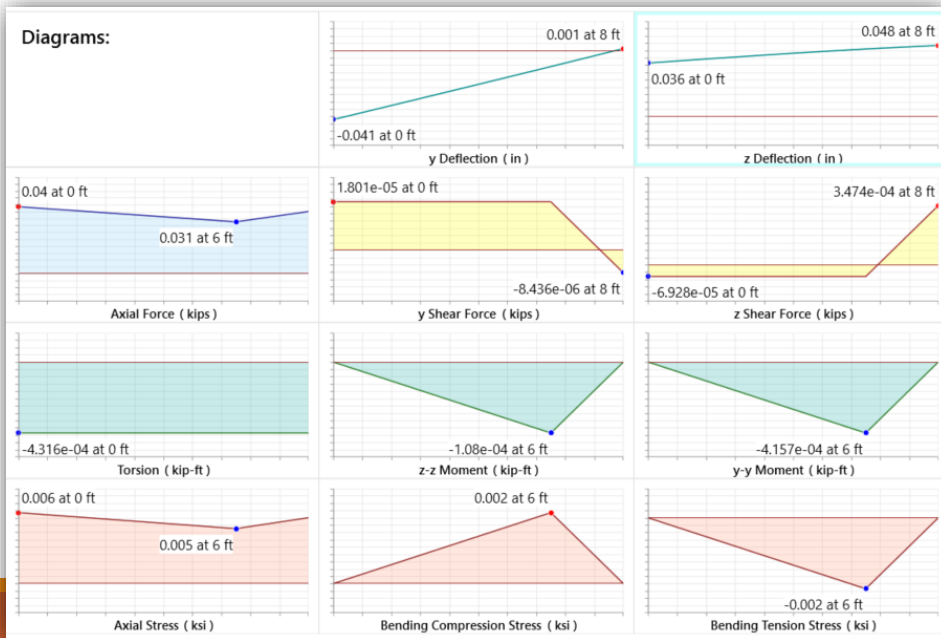
Material:	DF	Grade:	No.1	Nu:	0.3
Type:	Solid Sawn	Cm:	No	Therm. Coeff. (1e ⁻⁶ F ⁻¹):	0.3
Database:	Visually Graded	Emod:	1	Density (k/ft ³):	0.035
Species:	Douglas Fir-Larch				

Shape Properties:

F _y (ksi):	1	E (ksi):	1700	E _{min} (ksi):	621.025
F ₁ (ksi):	0.675	E mod:	1	b (actual) (in):	2.5
F _v (ksi):	0.18	COV _E (Table F1):	0.25	d (actual) (in):	2.5
F _c (ksi):	1.5				

Design Properties:

le2 (ft):	N/A	C _D :	1	Max Defl Ratio:	L/10000
le1 (ft):	N/A	R _B :	6.197	Max Defl Location:	0
le-bend top (ft):	L _{byy}	C _L :	1	Span:	N/A
le-bend bot (ft):	N/A	C _r :	1		
K _{y-y} :	1	C _{t0} :	1		
K _{z-z} :	1	C _p :	0.192		
y sway:	No				
z sway:	No				



Second-Floor Wood Girder:

Input Data:

Shape:	3X6 (nominal)	I Node:	N92
Member Type:	Beam	J Node:	N96
Length (ft):	28.2	I Release:	BenPIN
Material Type:	Wood	J Release:	BenPIN
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	5	J Offset (in):	N/A

Material Properties:

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

Shape Properties:

F _D (ksi):	1	E (ksi):	1700	E _{min} (ksi):	621.025
F _I (ksi):	0.675	E mod:	1	b (actual) (in):	2.5
F _V (ksi):	0.18	COV _E (Table F1):	0.25	d (actual) (in):	5.5
F _C (ksi):	1.5				

Design Properties:

le2 (ft):	N/A	C _p :	0	Max Defl Ratio:	L/10000
le1 (ft):	N/A	R _g :	0	Max Defl Location:	0
le-bend top (ft):	Lbyy	C _t :	0	Span:	N/A
le-bend bot (ft):	N/A	C _r :	0		
K _{y-y} :	1	C _u :	0		
K _{z-z} :	1	C _p :	0		
y sway:	No				
z sway:	No				

First-Floor Wood Beam:

Input Data:

Shape:	5X5 (nominal)	I Node:	N31
Member Type:	Beam	J Node:	N32
Length (ft):	15	I Release:	BenPIN
Material Type:	Wood	J Release:	BenPIN
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	5	J Offset (in):	N/A

Material Properties:

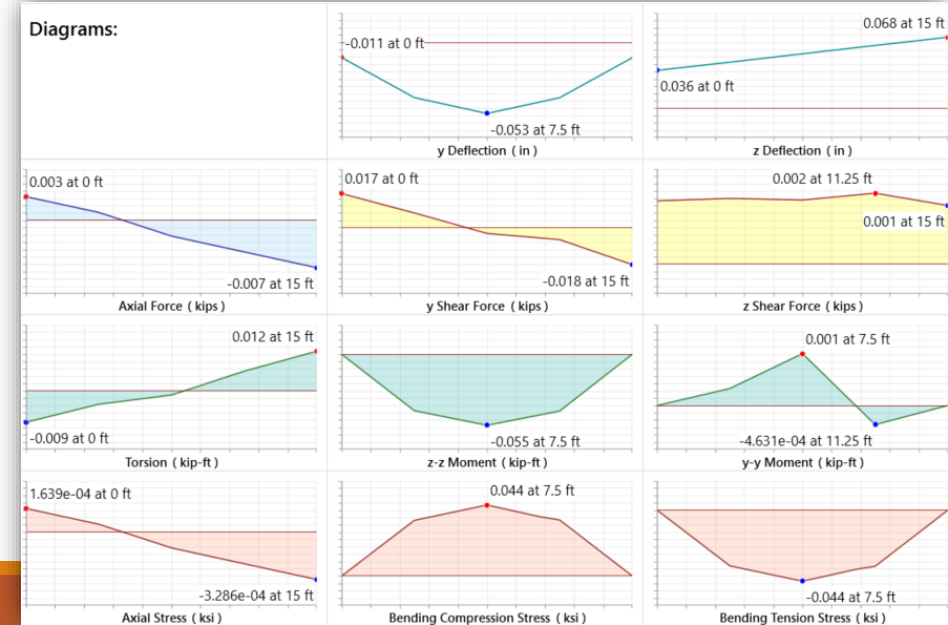
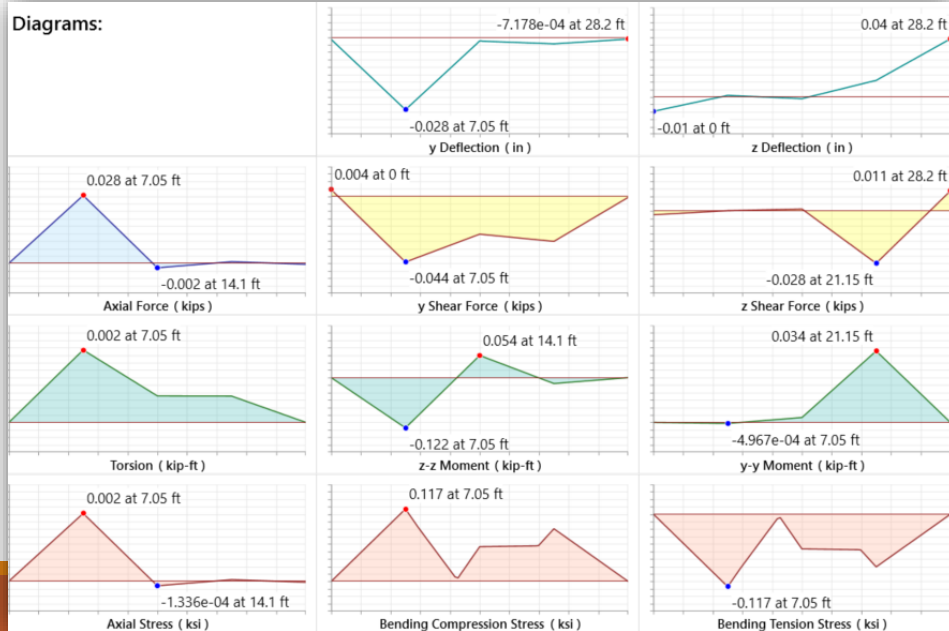
Material:	DF	Grade:	No.1	Nu:	0.3
Type:	Solid Sawn	Cm:	No	Therm. Coeff. (1e*F ⁻¹):	0.3
Database:	Visually Graded	Emod:	1	Density (k/ft ³):	0.035
Species:	Douglas Fir-Larch				

Shape Properties:

F _D (ksi):	1.2	E (ksi):	1600	E _{min} (ksi):	584.494
F _I (ksi):	0.825	E mod:	1	b (actual) (in):	4.5
F _V (ksi):	0.17	COV _E (Table F1):	0.25	d (actual) (in):	4.5
F _C (ksi):	1				

Design Properties:

le2 (ft):	N/A	C _p :	1	Max Defl Ratio:	L/4285
le1 (ft):	N/A	R _g :	6.325	Max Defl Location:	7.5
le-bend top (ft):	Lbyy	C _t :	1	Span:	1
le-bend bot (ft):	N/A	C _r :	1		
K _{y-y} :	1	C _u :	0.74		
K _{z-z} :	1	C _p :	0.279		
y sway:	No				
z sway:	No				



Structural Analysis

Wooden Studs:

- Central Attic Wooden Stud
 - Supports heavy live load and dead load from roof trusses

Wooden Truss:

- Diagonal Roof Truss
 - Has live load specifically located on it

Central Attic Wood Stud:

Input Data:

Shape:	3X3 (nominal)	I Node:	N658
Member Type:	Column	J Node:	N1093
Length (ft):	8	I Release:	BenPIN
Material Type:	Wood	J Release:	Fixed
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	5	J Offset (in):	N/A

Material Properties:

Material:	DF	Grade:	No.1	Nu:	0.3
Type:	Solid Sawn	Cm:	No	Therm. Coeff. (1e ⁻⁶ F ⁻¹):	0.3
Database:	Visually Graded	Emod:	1	Density (k/ft ³):	0.035
Species:	Douglas Fir-Larch				

Shape Properties:

F _D (ksi):	1	E (ksi):	1700	E _{min} (ksi):	621.025
F _T (ksi):	0.675	E mod:	1	b (actual) (in):	2.5
F _V (ksi):	0.18	COV _E (Table F1):	0.25	d (actual) (in):	2.5
F _C (ksi):	1.5				

Design Properties:

le2 (ft):	N/A	C _D :	0	Max Defl Ratio:	L/240
le1 (ft):	N/A	R _B :	0	Max Defl Location:	0
le-bend top (ft):	Lbyy	C _T :	0	Span:	N/A
le-bend bot (ft):	N/A	C _F :	0		
K _{y-y} :	1	C _{R1} :	0		
K _{z-z} :	1	C _P :	0		
y sway:	No				
z sway:	No				

Diagonal Wood Roof Truss:

Input Data:

Shape:	2-2X4 (nominal)	I Node:	N1094
Member Type:	VBrace	J Node:	N1093
Length (ft):	24.743	I Release:	BenPIN
Material Type:	Wood	J Release:	Fixed
Design Rule:	Typical	I Offset (in):	N/A
Number of Internal Sections:	5	J Offset (in):	N/A

Material Properties:

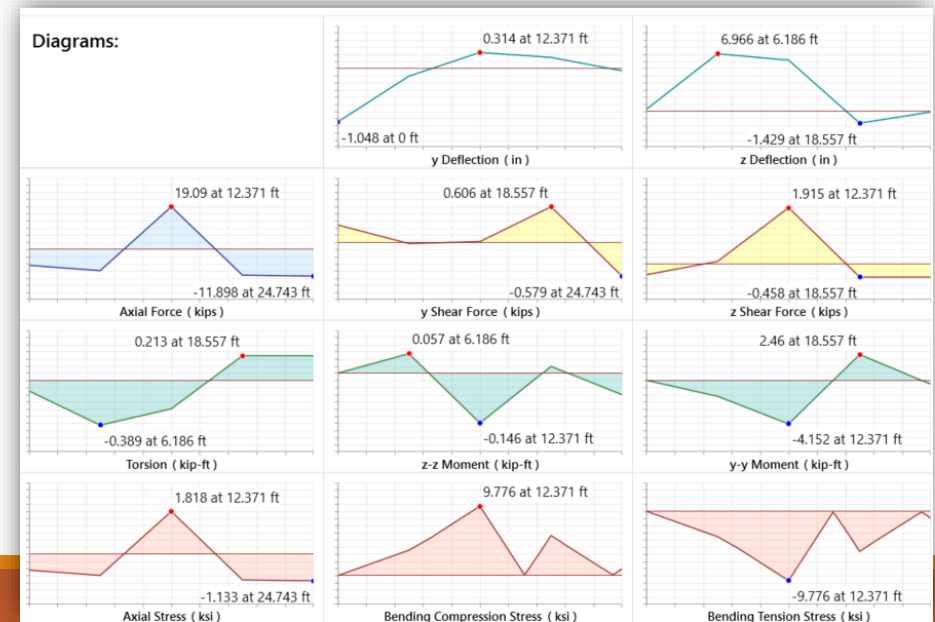
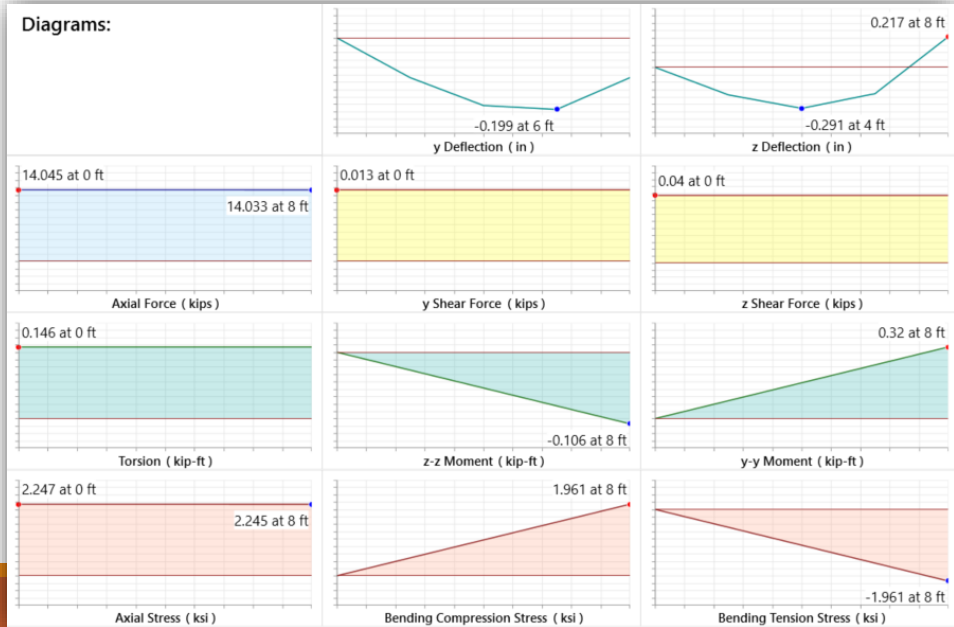
Material:	DF	Grade:	No.1	Nu:	0.3
Type:	Solid Sawn	Cm:	No	Therm. Coeff. (1e ⁻⁶ F ⁻¹):	0.3
Database:	Visually Graded	Emod:	1	Density (k/ft ³):	0.035
Species:	Douglas Fir-Larch				

Shape Properties:

F _D (ksi):	1	E (ksi):	1700	b (actual) (in):	3
F _T (ksi):	0.675	E mod:	1	d (actual) (in):	3.5
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 :	0	Max Defl Ratio:	L/43
le1 (ft):	N/A	R _B :	0	Max Defl Location:	0
le-bend top (ft):	Lbyy	C _T :	0	Span:	N/A
le-bend bot (ft):	N/A	C _F :	0		
K _{y-y} :	1	C _{R1} :	0		
K _{z-z} :	1	C _P :	0		
y sway:	No	K _F :	1		
z sway:	No				



Cost Analysis

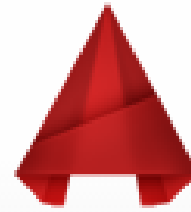
- Material takeoff shows material, size, number of pieces, length [ft], and weight [K] of members

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							
Material	Size	Pieces	Length[ft]	Weight[K]	Length[ft] per Piece	Cost per Piece	Total Cost for Pieces
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	
Concrete Members							
Material	Size	Pieces	Length[ft]	Weight[K]	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						

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				
Conc3000NW	CRECT8X8	9	1.2	4.64
Total Concrete		9	1.2	4.64

Conclusion

- Process consists of designing floor plan, then 3D model, next the structural analysis of model
- Expanded my knowledge of using AutoCAD and RISA
- Learned to fix certain issues within programs for different types of situations



AUTOCAD



RISA-3D