Timber-Strong Design Build Competition

Astro Jacks Engineering

CENE 486C

5/2/2025

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Project Overview

Design – Build Competition

- Analyzed and Designed a light framed timber structure
- Created 2D and 3D models
- Prefabricated structure per plans at NAU
- Competed at the ISWS Student Symposium
    - American Society of Civil Engineers
    - April 10th, 2025
    - Tuscon, Arizona – University of Arizona

Client: Mark Lamer

Figure 1: Astro Jacks practice Construction day [1]

Constraints - Design

- Height < 12'
- 1st Story 6' x 8'
- 2nd Story 7'4" x 8'
- 1'4" Floor System Overhang
- 4'1" Floor Cantilever Beam
- 1st Story: 1 Door, 3 Windows
- 2nd Story: 4 Windows

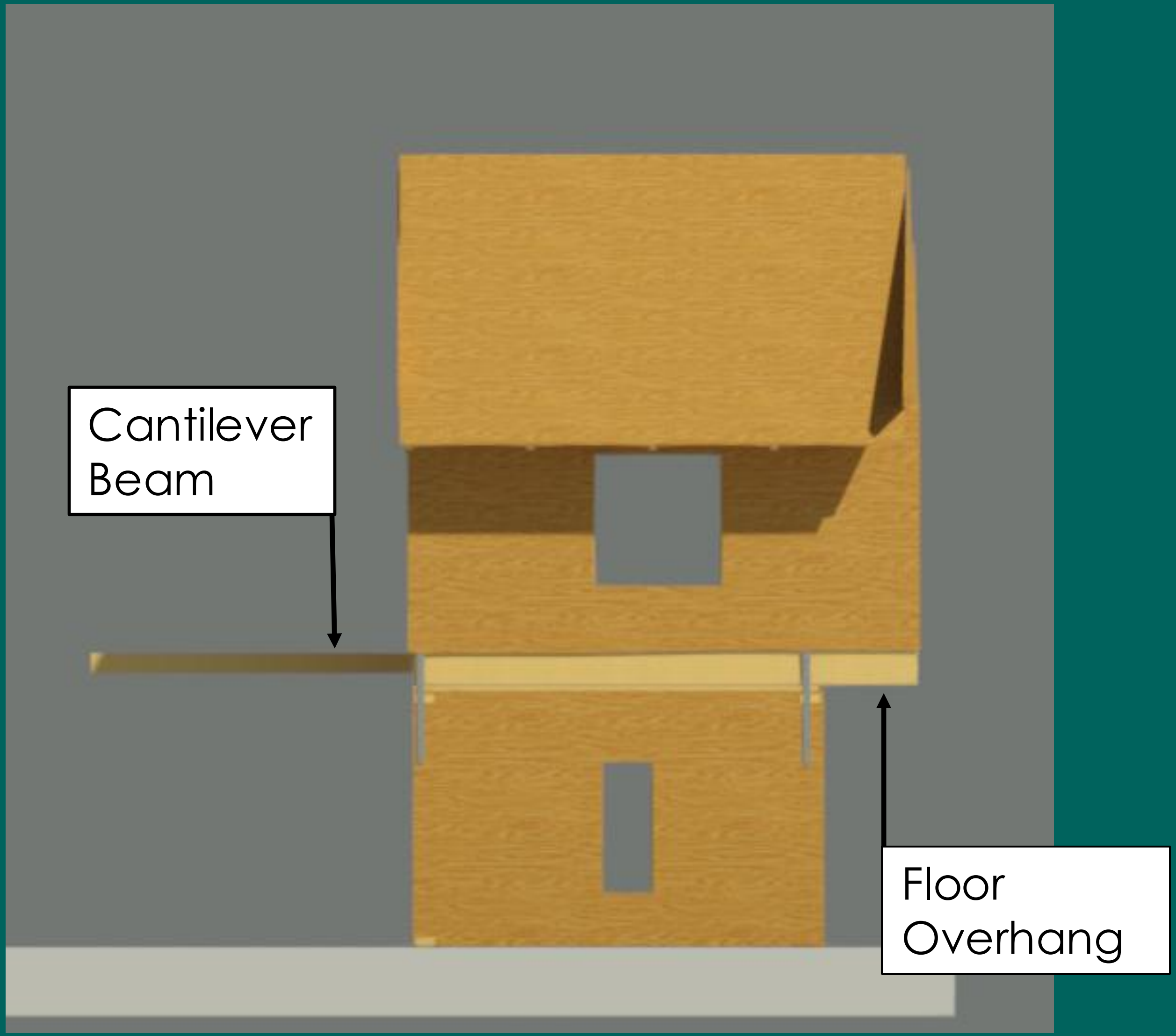


Figure 2: Revit Elevation view

Constraints - Construction

- Restricted to Nominal Lumber 2x4 or larger
- Had to practice safe building practices
- Had to complete Ladder Safety Course
- Floor overhang mechanically shored until structure completion
- Simpson Stong Tie hardware not installed until build day
- PPE included hardhats, safety glasses, high-vis vests, and gloves
- Only 4-6 builders allowed on site

Figure 3: Temporary Shoring

Constraints - Loading

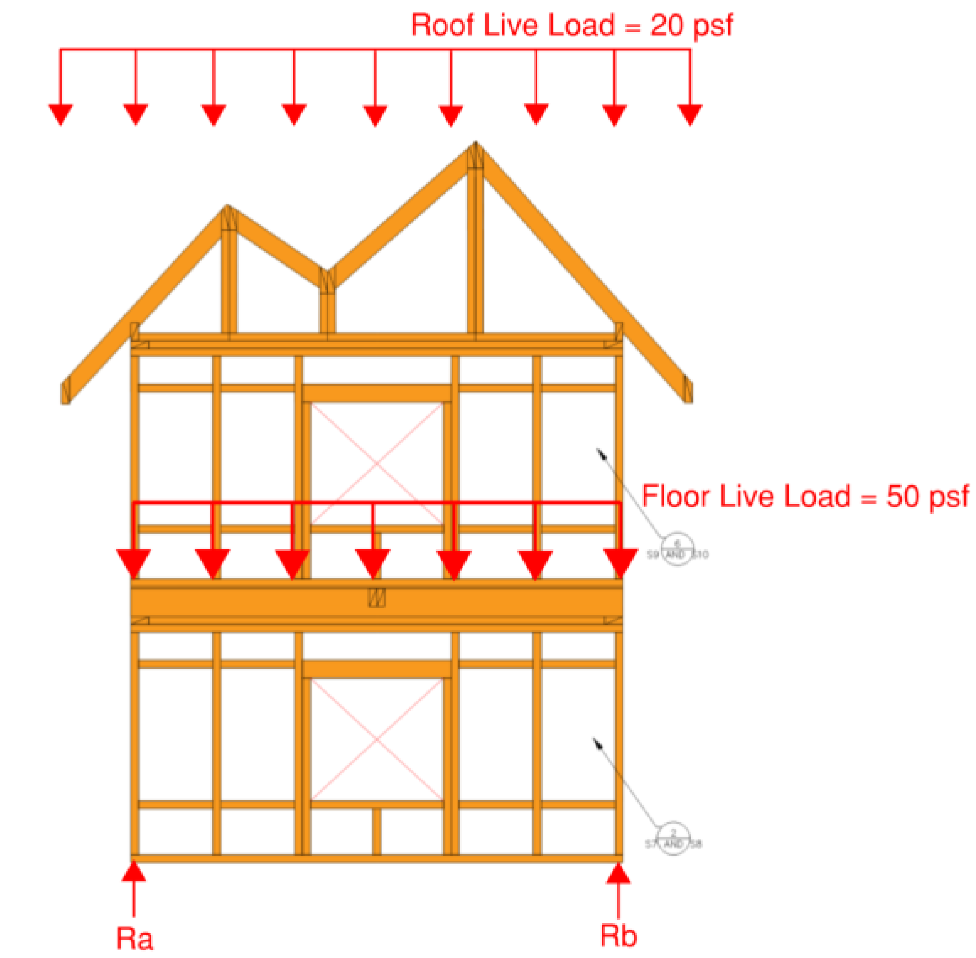


Figure 4: Gravity Loading

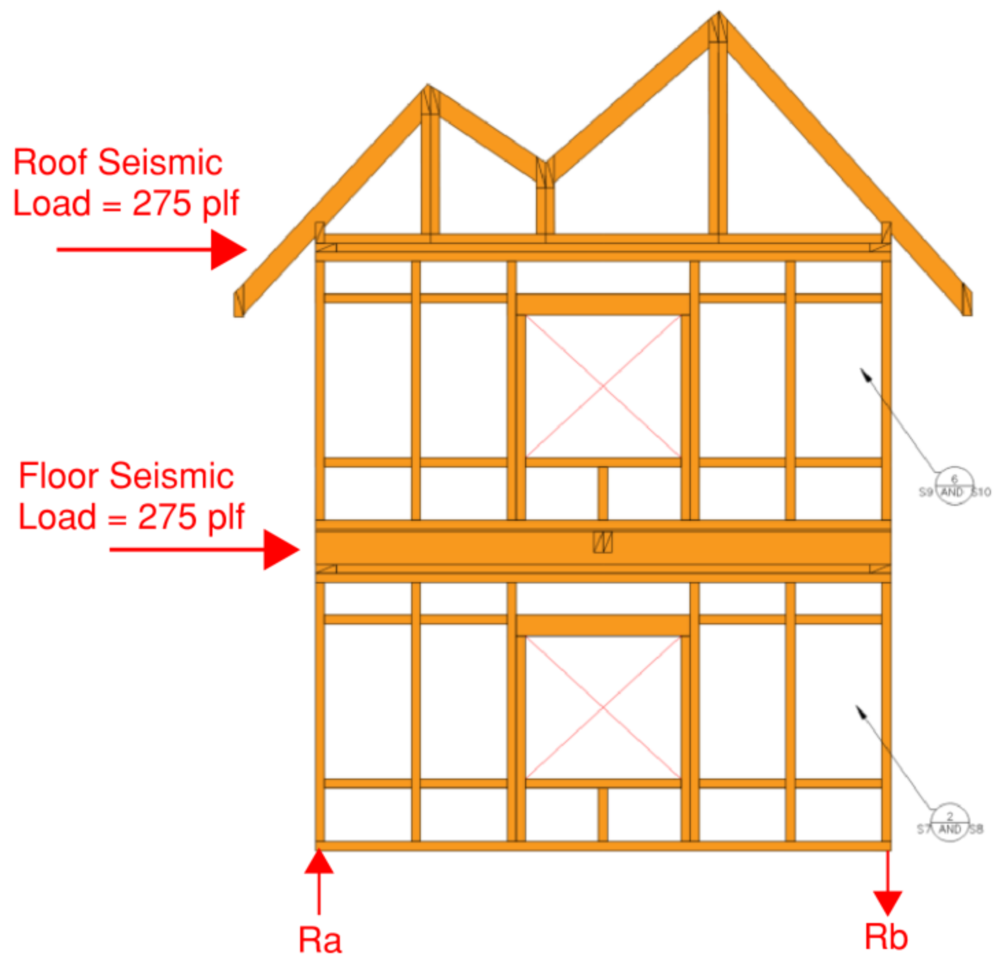


Figure 5: Lateral Loading

Initial Design- Timber Type

Table 1: Timber Type Decision Matrix

Timber Type Decision Matrix		Douglas Fir		Southern Pine		Douglas Fir Larch		Hem Fir		Spruce Pine Fir	
Criteria	Weight (%)	Scor e	Weight Score	Score	Weight Score	Score	Weight Score	Score	Weight Score	Score	Weight Score
Cost	30	1	0.3	2	0.6	1	0.3	2	0.6	3	0.9
Availability	70	1	0.7	2	1.4	1	0.7	3	2.1	2	1.4
TOTAL	100		1.0		2		1.0		2.7		2.3

- **Key Criteria:** Cost (30% weight) and Availability (70% weight).
- **Why Availability Matters:** Majority of lumber was donated — Hem Fir was most available.
- **Scoring System:** 1 (least favorable) to 3 (most favorable) for each criterion.

Initial Design- Roof Design Alternatives

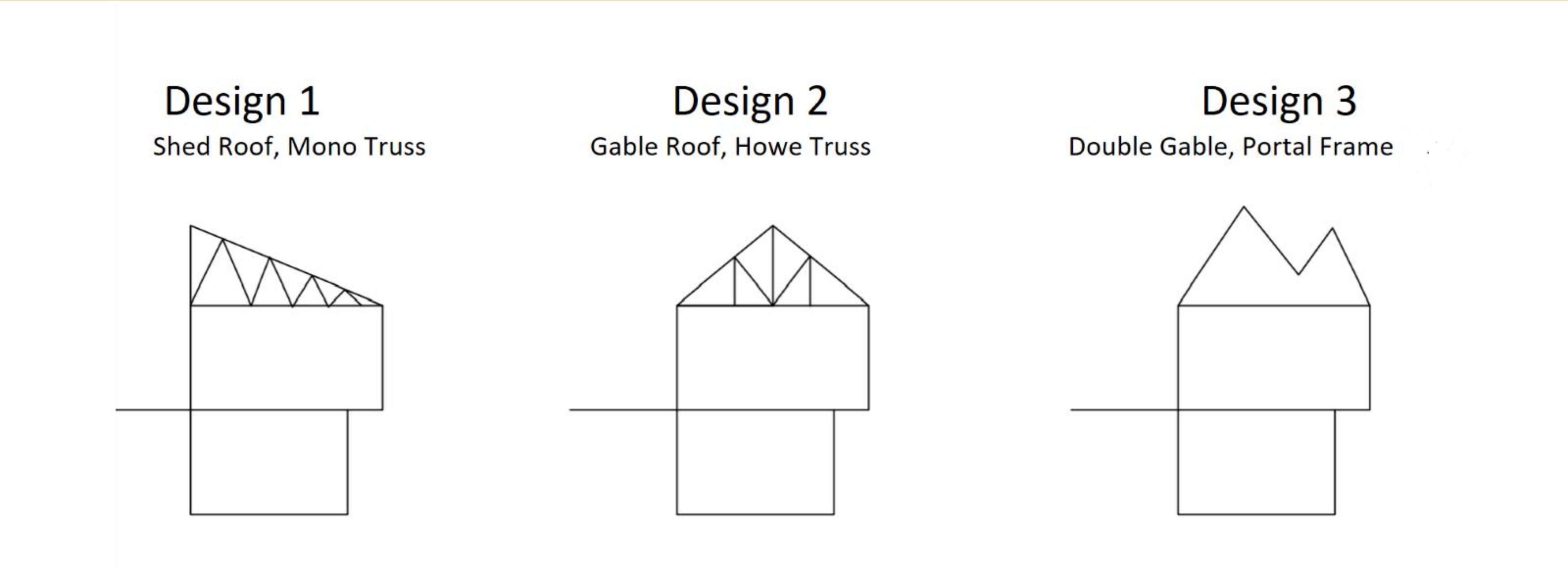


Figure 6: Sketches of the Roof Design Alternatives

Initial Design- Design Alternatives

Table 2: Design Decision Matrix

Design Decision Matrix		Design 1		Design 2		Design 3	
Criteria	Weight (%)	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Structural Integrity	30	2	0.6	3	0.9	1	0.9
Cost	10	2	0.2	2	0.2	1	0.1
Constructability	20	2	0.4	3	0.6	2	0.4
Aesthetic	20	2	0.4	1	0.2	3	0.6
Functionality	10	1	0.1	2	0.2	1	0.1
Sustainability	10	2	0.2	2	0.2	3	0.3
TOTAL	100		1.9		2.3		2.4

- **Key weights:** Structural Integrity (30%), Aesthetics & Constructability (20% each).
- Scored 1–3 based on performance in each category.
- **Design 3 chosen:** best overall score (2.4), strong in aesthetics & sustainability.
- **Design 2:** strongest structurally, easiest to build.
- **Design 1:** average across most categories.

Final Design – Calculations (Gravity Design)

- All Calculations Performed Using
  - NDS
  - NDS Supplement
  - SDPWS
- Calculations done using ASD
- Minimum Depth of Beams were found based on Maximum Shear, Flexure, and Compression

Table 3: Roof Gravity Design

Roof Gravity Design						
Member	Required Force			Required Depth (in)	Provided Depth (in)	Factor of Safety
	Axial (lbs)	Shear (lbs)	Moment (lb*ft)			
Rafter	-	78.25	544.46	1.22	3.5	1.69
Ridge Beam	-	82.4	2333.3	2.71	5.5	1.42
Ridge Beam Studs	133.3	-	-	0.048	3.5	8.54

Flexure Eq. (3.3-2)

$$f_b = \frac{M}{S} = \frac{6M}{bd^2}$$

$M = Maximum\ Moment$
$b = Width\ of\ Beam$
$d = Depth\ of\ Beam$

Shear Eq. (3.4-2)

$$f_v = \frac{3V}{2bd}$$

$V = Maximum\ Shear$
$b = Width\ of\ Beam$
$d = Depth\ of\ Beam$

Final design – Continuous Load Path

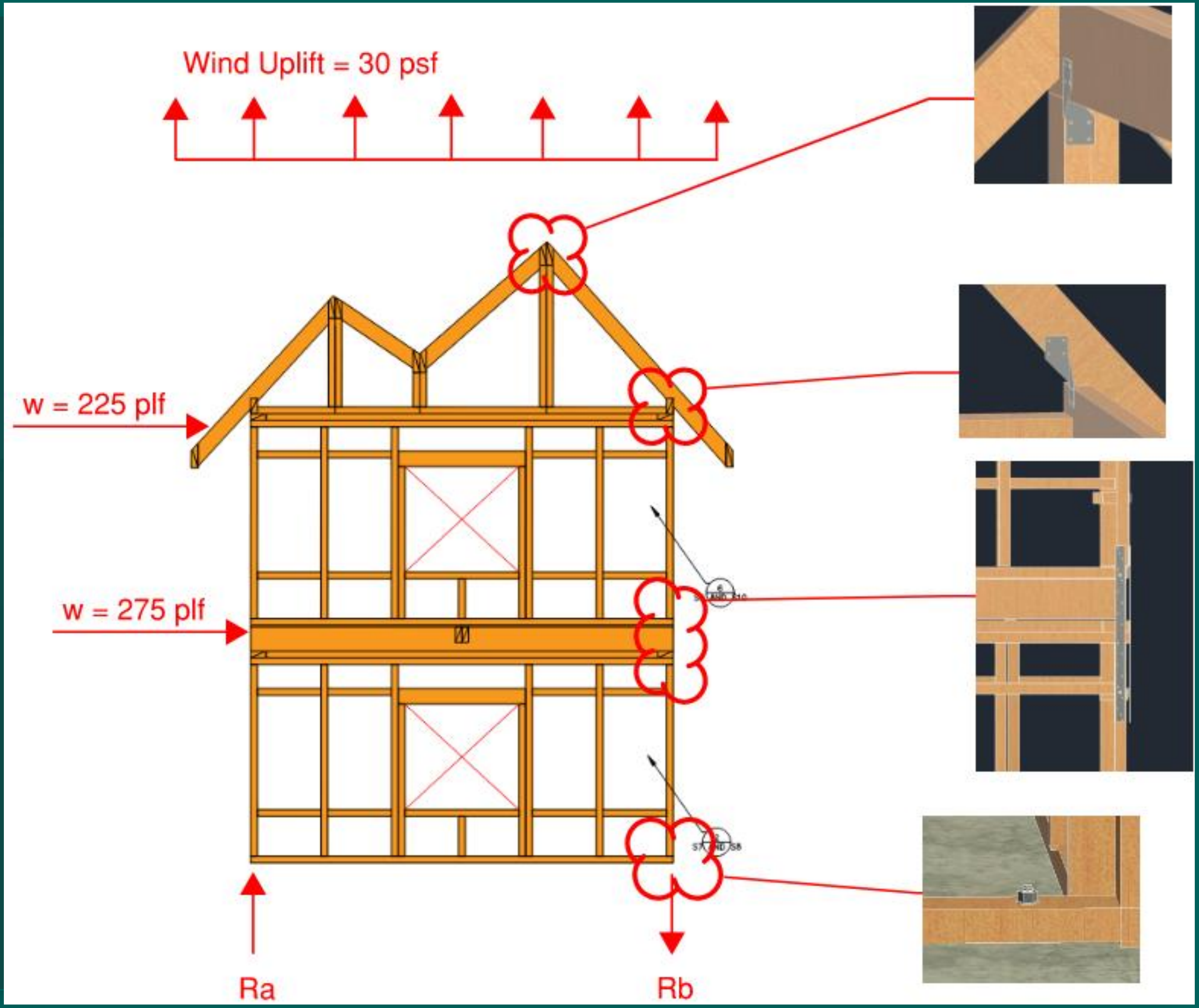
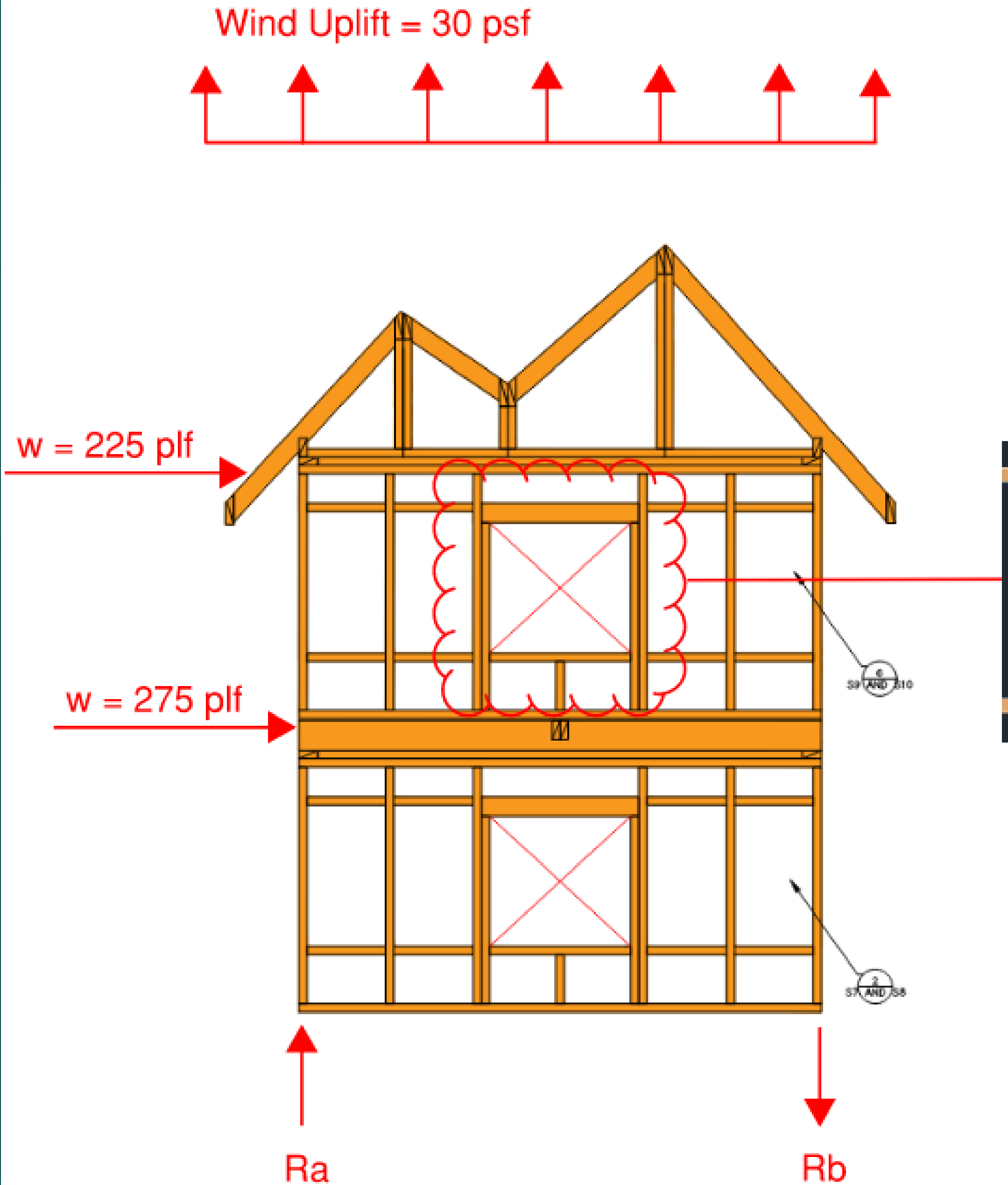


Figure 7: Continuous Load Path

Final design – Continuous Load Path (Force Transfer Around Openings)



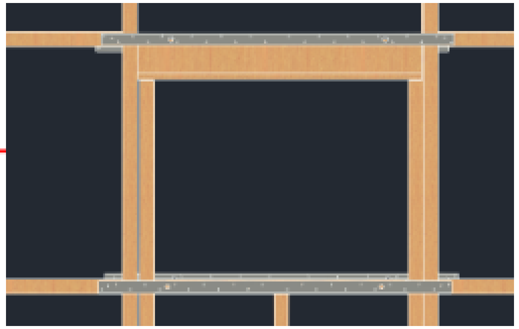


Figure 8: Continuous Load Path for Openings

Final Design – Lateral Design Factor of Safety

Table 4: Factor of Safety

Factor of Safety				
	Component	Calculated Factor of Safety	Target Factor of Safety	Percent Difference
Diaphragm	Roof	2.1	1.5	33%
	Floor	2.3		42%
	Average	2.1		33%
Shear Wall	First Story	1.91		24%
	Second Story	1.57		5%
	Average	1.77		17%

Final Design – Deflection

Table 5: Predicted Deflection Values

Load Placement From Exterior Wall to delta	Deflection (in)
4’0”	0.62
3’9”	0.53
3’6”	0.50

0.5 in. < Deflection < 1.0 in. ✓

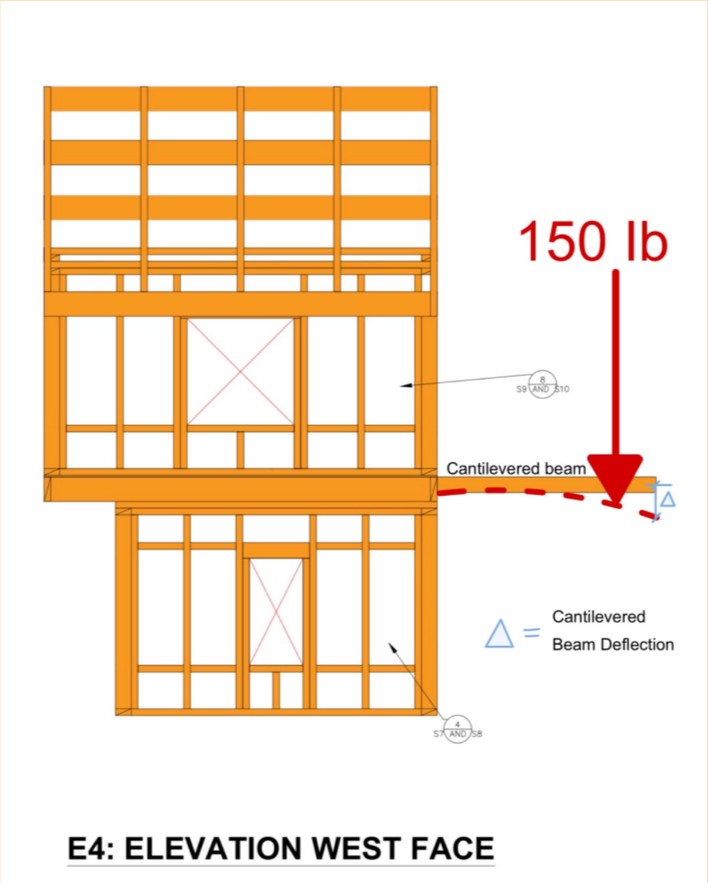


Figure 9: Deflected Cantilever with Point Load

Modeling – 2D Structural Drawings

Competition Requirements

- Framing Plans
- Shear Wall connection Details
- Panelized Diaphragms
- Shear wall sheathing type
- Fastening schedule
- Anchorage to the foundation
- Plan, Profile, Cross Sectional details and views

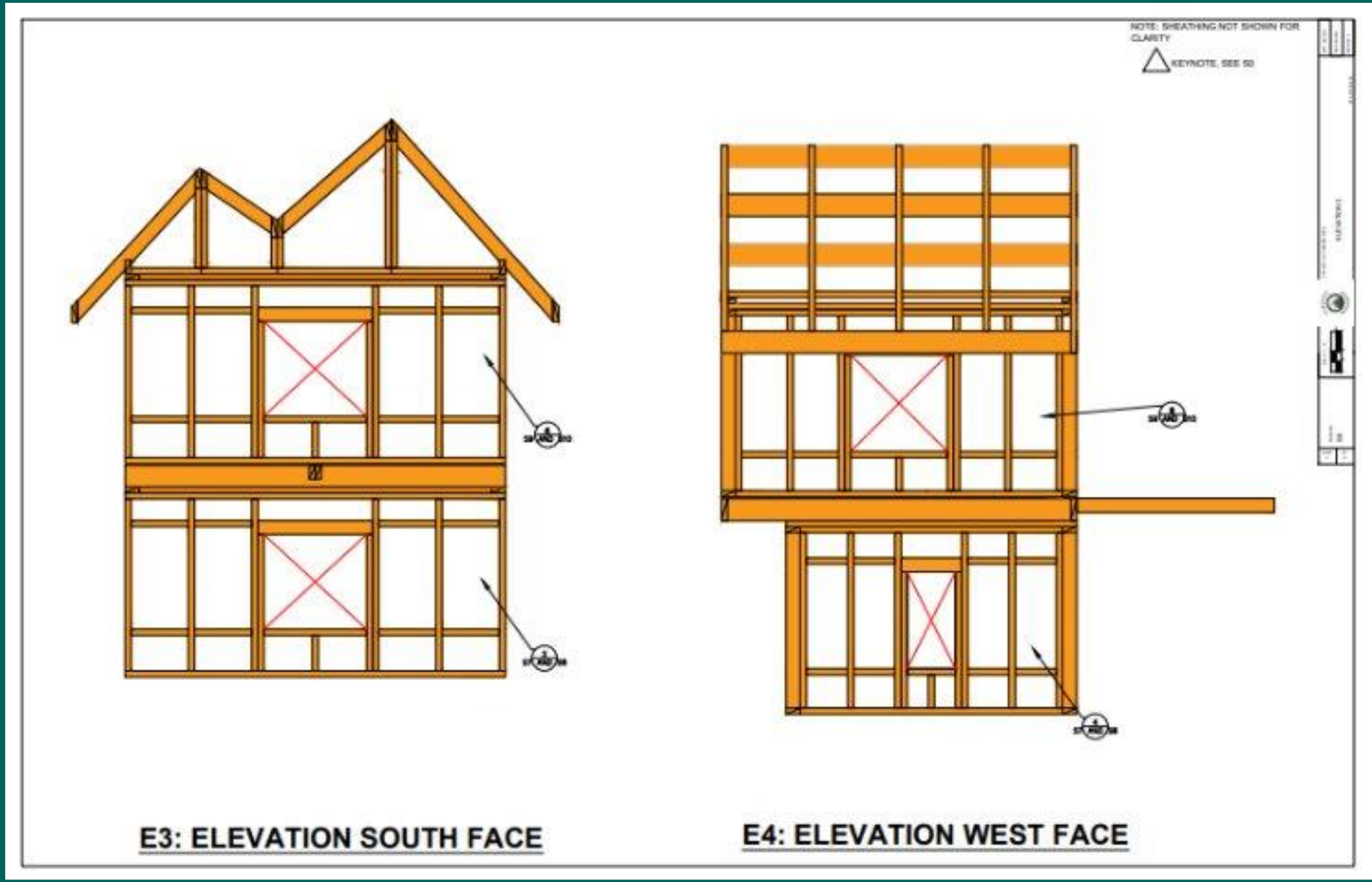


Figure 10: Elevation Views from the Plan Set

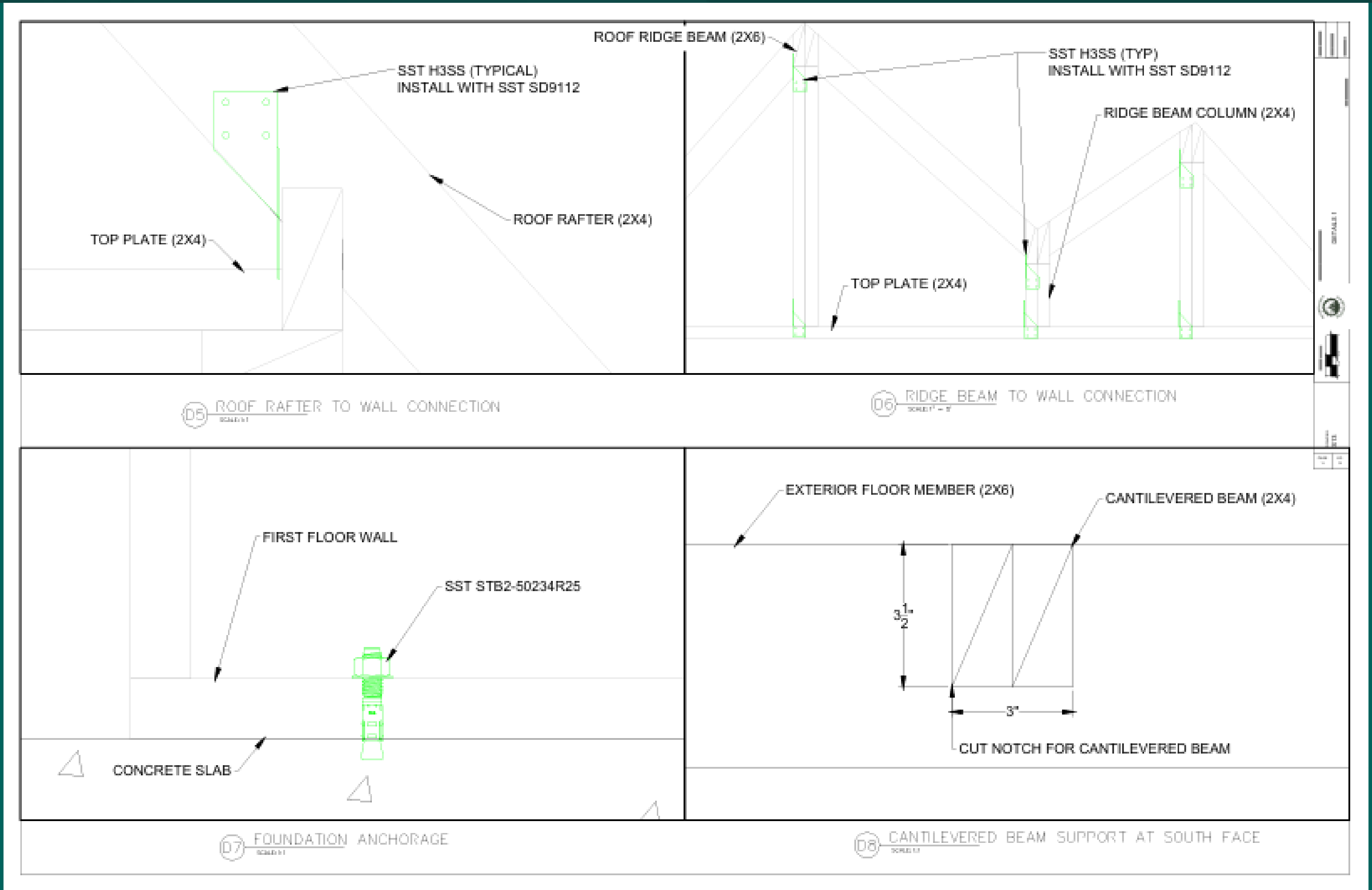


Figure 11: Drawing Connector Details

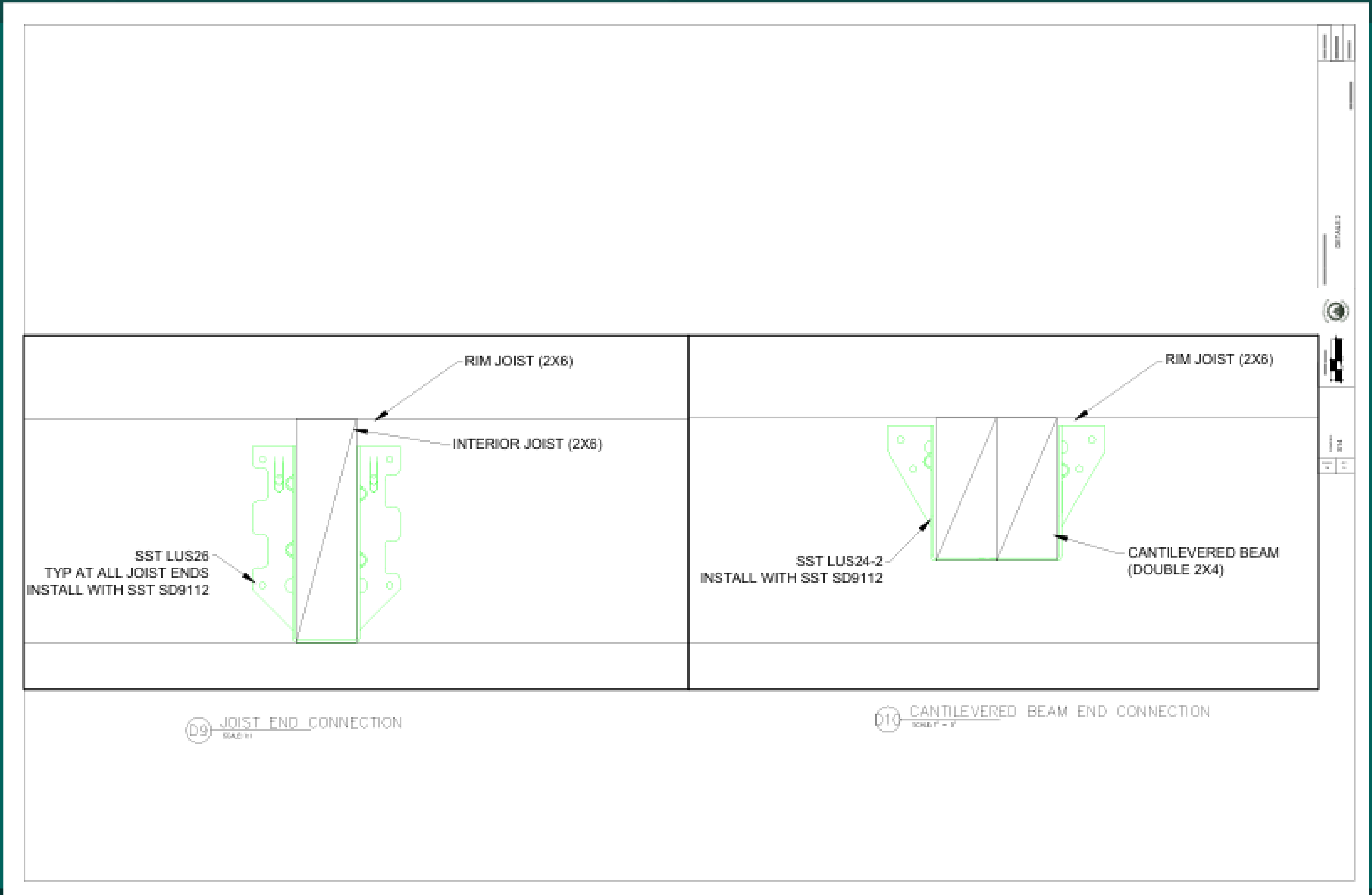


Figure 12: Drawing Details

Modeling – 3D BIM Model

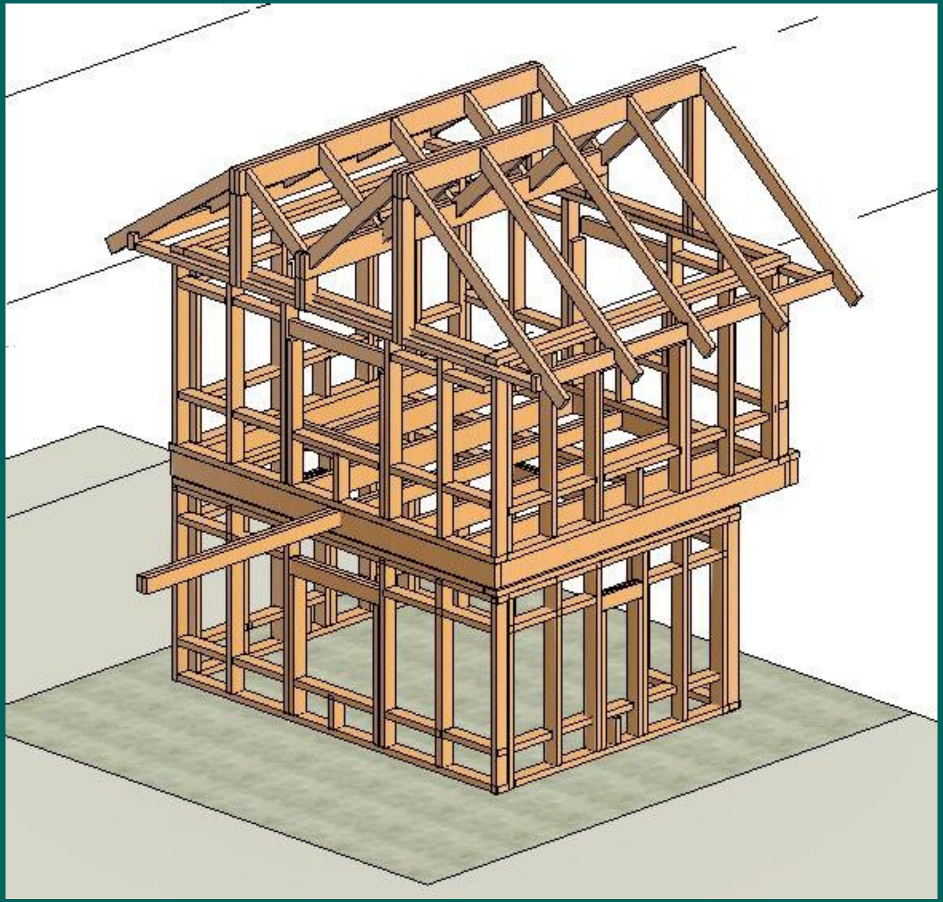


Figure 13: Framed Model in Revit

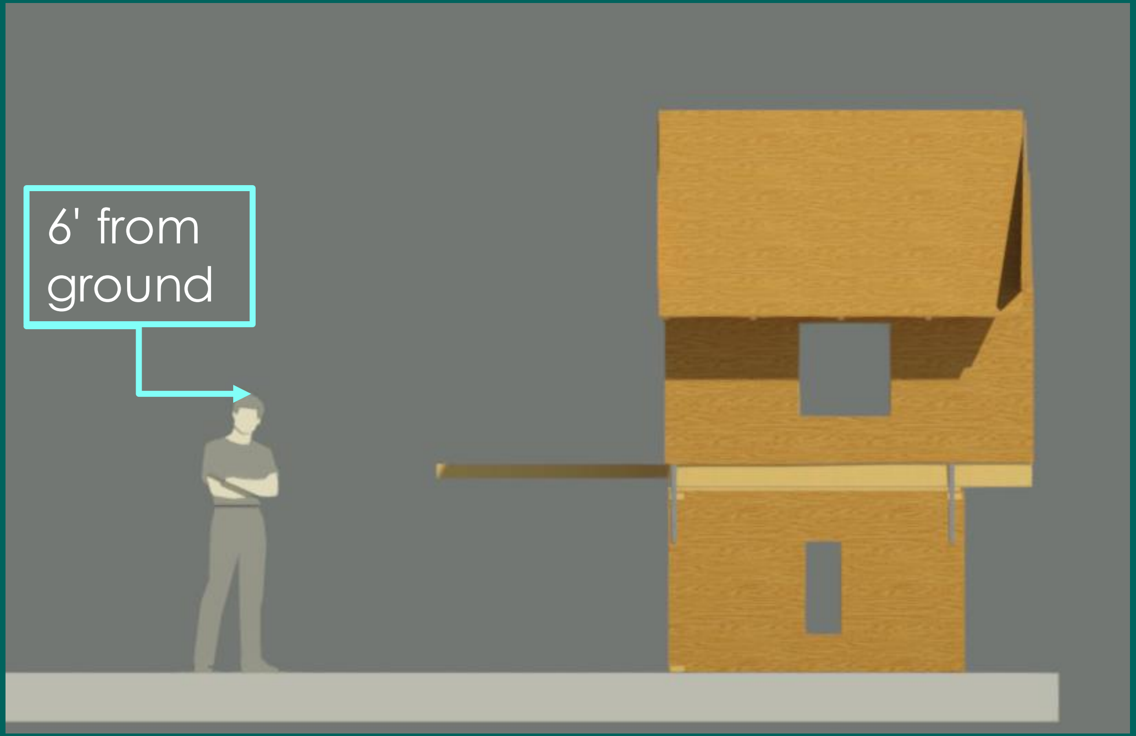


Figure 14: Elevation View in Revit

Construction – Prefabrication

Figure 15: Prefabricating 1st Story

Figure 16: 1st Story Wall partially framed

Figure 17: 1st Story Completed

Competition

- Panels Staged Prior to Competition
- Time limit of 90 minutes
- Restricted 18’x18’ area
- Limited to ONLY battery powered drills

Figure 18: Competition Day with Structure laid out


Astro Jacks Engineering

Scoring

Table 5: Score Sheet

Category	Maximum Points	Your Score
PHASE 1: REPORT		
Design Strength and Durability Analysis	82	57.5
Sustainable Design	18	18
Budget	20	13
Report Requirements	10	10
Subtotal - Phase 1	130	98.5
PHASE 2: DRAWINGS, BIM, VISUAL AID, GRAPHICS		
Visual Aid	10	10
Creativity & Aesthetics	20	25
BIM (Deliverables)	70	106
Deductions	-	-7.5
Subtotal - Phase 2	150	133.5
PHASE 3: PRESENTATION		
Presentation	10	9
Subtotal - Phase 3	10	9
BUILD DAY: CONSTRUCTION		
Accuracy and Demonstration of Load Path	50	41
Quality, Aesthetics and Speed	60	49
Structure Requirements	20	20
Build Time (BONUS)	5	1
Subtotal - Build Day	130 (+5)	111
TOTAL POINTS	420 (+5)	352

Competition

2025 ASCE Timber-Strong Design Build competition during the ISWS Student Symposium:

- **1st Place Overall: ASCE 2025 Design Build**
- **1st Place: BIM Modeling**

Measured Deflection

- At 3'9" = 0.83"

Predicted deflection

- At 3'9" = 0.53"

Figure 19: Measuring Deflection

Figure 20: Banquet with our 1st place plaques

Construction Lessons Learned

- **Accurate measurements are critical**
  - Inaccurate cuts waste material
- **Use Chalk Lines**
  - Keeps cuts and edges straight and aligned.
- **Detailed Construction Plans Matter**
  - Every measurement should be labeled
  - Reduces on-site guesswork
- **Hammering Takes Skill**
  - Requires strength and precision
- **Drilling is Tougher Than It Looks**
  - Requires pressure, balance, and a steady hand.
- **Always Wear Gloves**
  - Protects against splinters and rough handling of wood.

Figure 21: Prefabrication of Panel

Impacts

Impact	**Timber**	**Cold Formed Steel**
Social	+ Local sourcing − Pest prone	+ Fire-resistant − Needs specialized labor
Economic	+ Lower initial cost − Higher maintenance	+ Faster completion − Higher shipping cost
Environmental	+ Reduces CO_2 − Degrades faster	+ Recyclable − Non-renewable

Figure 22: Timber vs Cold Formed Steel

References

- HomeCo Hardware & Lumber Logo: https://www.myhomco.com/?srsltid=AfmBOopEHG_jIgXlMqJBZCaXQ5CG43aUL6aO9JV1T9zPrr8qSxS_7yZU
- SImpson Strong-Tie Logo: https://www.strongtie.com/
- Timber vs Cold Formed Steel: https://gharpedia.com/blog/benefits-of-using-steel-vs-wood/

Thank You