2024 – 2025 ASCE TIMBER-STRONG

Final Phase Report

ASTROJACKS ENGINEERING

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CENE 486C

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Abbreviations

APA: American Plywood Association

ASCE: American Society of Civil Engineers

ASD: Allowable Stress Design

AWC: American Wood Council

BIM: Building Information Modeling

CECMEE: Civil Engineer, Construction Management, and Environmental Engineer

INT: Engineering Intern

ISWS: Intermountain Southwest Student Symposium

NDS: National Design Specification

RFI: Request for Information

SAF: Safety Officer

SENG: Senior Engineer

SIPS: Structural Insulated Panels

SPWS: Special Design Provisions for Wind and Seismic

SST: Simpson Strong-Tie

STENG: Structural Engineer

SUPR: Superintendent

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Acknowledgements

We would like to thank the sponsors for this project for their support and donations (Simpson Strong Tie, The American Society of Civil Engineers, The American Wood Council, The American Plywood Association).

We would also like to thank Northern Arizona University and their faculty, specifically our Technical Advisor, Dr. Robin Tuchscherer, and our client, Marl Lamer. We thank them for their support and guidance throughout the project.

Lastly, we would like to thank our mentees for their help throughout the project.

1.0 Project Introduction

1.1 Project Purpose

The purpose of ASCE Timber-Strong Student Competition is to bring civil engineering students together to gain hands on experience with structural design and construction for timber. The competition guides students to design and build a two-story, light framed wood structure. The structure is to be designed sustainable and aesthetically pleasing. The competition has sponsor from companies including American Wood Council (AWC), Simpson Strong-Tie (SST), and the American Plywood Association (APA). The approach for the project is design-build and allows students to show their creativity and skills they have learned in their classes.

Wood is the main focus of the competition because it is renewable in nature and has many environmental advantages. Unlike other materials that are energy-intensive to make like steel and concrete that are traditionally used, wood is more sustainable and reduces carbon emissions. As trees grow they absorb carbon dioxide from the atmosphere, and when the lumber is used the carbon still stays stored in the wood for the life of the structure. It is still important to know that wood is only sustainable material if it is harvested the right way. The right way is to cut the trees down at a slower rate than it can grow back. When the carbon is stored in the wood during its use, that carbon can still be released into the atmosphere, if the wood decomposes or burned it will be released.

Throughout the competition the students gain experience in engineering and construction practices to prepare them for the real world. They use structural analysis, design calculations, Building Information Modeling (BIM), scheduling, and construction planning. Using knowledge and skills from courses, students directly apply concepts like project management, teamwork, communication, and problem solving and apply them to the project.

1.2 Project Overview

Northern Arizona University has been competing in the ASCE TimberStrong competition since 2018 when the competition began. The project started off as a small-scale structure to a full two-story timber building, this allows students to gain a deeper understanding of the concepts of wood design and construction methods.

The project includes serval phases that are crucial to finish the project. Starting off with initial designs, structural analysis, and BIM Modeling. Then construction drawings are put together and the prefabrication of the building is started. Once all the prefabrication is completed, all the comments are transported to University of Arizona where the competition is held. This is where the team will showcase their work and compete against other universities. As a team of 6 builders the structure will be built in under 90 minutes.

2.0 Project Background

2.1 Allowable Stress Design

The competition requires Allowable Stress Design (ASD) to be used in the structural design calculations. This method makes sure the applied load given by the competition does not generate enough stress to exceed capacity. Using design process in the AWC Special Design Provisions for Wind and Seismic (SDPWS) and the AWC National Design Specification (NDS) standards, the design will be created to meet the requirements of the competition.

2.2 Timber Grade Species

There are five different levels of grades of wood, it is based on the strength, quality, and appearance of the wood. The grade determines how it should be used in construction. In the table below it shows an overview of the characteristics for each grade of wood.

TABLE 1: GRADE OF TIMBER

Grade	Condition	Description
1 – Construction	Moderate number of tight knots	Best used for general construction and when appearance important
2 – Standard	More number of knots	Used when more knots are acceptable
3 – Utility	Has splits and knotholes	Can be used in nonstructural work
4 – Economy	A lot of splits and defects	Used for temporary or low loads
5 – Economy	Large number of defects	Can't be used for many structures, used more for secondary applications

The competition gives a specific type of timber species to use for the structure these were Douglas Fir (DF), Southern Pine (SP), Douglas Fir-Larch (DF-L), Hem-Fir (HF) or Spruce-Pine-Fir (SPF). The competition selects these species for their performance, cost, and workability. The range of different types and properties allows for each team to pick the species that best fits their project. In the table below is shows the five species that can be used for the project.

TABLE 2: TIMBER SPECIES

Timber Species
Douglas Fir (DF)
Southern Pine (SP)
Douglas-Fir-Larch (DFL)
Hem-Fir (HF)
Spruce-Pine-Fir (SPF)

2.3 Design Requirements

The critical structural parameters the building must meet, including dimensional constraints, applied loads, and performance criteria. The following subsections detail the gravity, lateral, and concentrated loads considered, the required continuous load path, and the specific design and deflection guiding structural performance.

2.3.1Structure Dimensions

The structure is a two-story wood light-frame building. The Ground Level Floor Plan has a maximum dimension of 6’-0” x 8’-0”, while the Second Level Floor Plan extends to 7’-4” x 8’-0”, measured to the outside face of the wood stud walls. Refer to Figure 1 below.

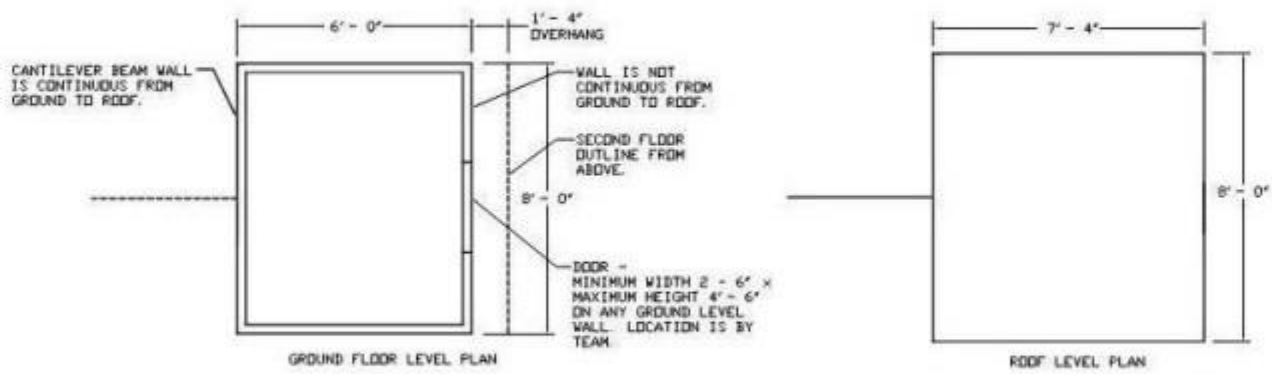

FIGURE 1: FLOOR LEVEL DIMENSIONS

Additional structural elements such as wall sheathing, roof sheathing, roof eaves, and the cantilever floor beam extend beyond the footprint. Refer to Appendix A: Framing Envelope, for a visual glance at the structures dimension requirements from the competition rulebook. [1]

2.3.2 Structure Loads

The structure must be designed to withstand vertical gravity and lateral loads (seismic and wind). Gravity loads include roof dead load (self-weight), roof live load of 20 psf, floor dead load (self-weight), and a floor live load of 50 psf. Additionally, a point load of 150 lbs is applied at the end of the cantilever floor beam, which must be designed for shear and bending, refer to Figure 2 below. The predicted deflection of this beam must be within 0.5 to 1 inch when loaded at distances of 3.5 feet, 3.75 feet, and 4.0 feet from the exterior wall.

Lateral design loads include seismic forces of 275 plf at the roof diaphragm and 225 plf at the floor diaphragm, and wind uplift pressure of 30 psf on both surfaces of roof overhangs. The structure must provide a continuous load path to resist uplift, overturning, and sliding forces.

2.3.2.1 Gravity Loads

Gravity loads include the dead and live loads acting vertically on the structure. These must be distributed and transferred through the framing system down to the foundation. Table 3 below summarizes the gravity loads considered in the design.

TABLE 3: GRAVITY LOADS

Load Type	Magnitude
Roof Dead Load	Self-weight
Roof Live Load	20 psf
Floor Dead Load	Self-weight
Floor Live Load	50 psf

2.3.2.2 Lateral Loads

Lateral loads include seismic and wind forces, which act horizontally on the structure and must be resisted through shear walls and diaphragm action. The structure must be designed to prevent racking, sliding, or overturning under these loads. Table 4 summarizes the lateral loads used in the design.

TABLE 4: LATERAL LOADS

Load Type	Magnitude
Seismic Load at Roof Diaphragm	275 plf
Seismic Load at Floor Diaphragm	225 plf
Wind Uplift Pressure	30 psf (roof overhangs)

2.3.2.3 Concentrated Load

The concentrated load is a 150 lb point load applied at the end of the cantilever floor beam. This simulates a deflection test condition and represents a critical design component. The beam must resist both shear and bending, and its deflection must remain within 0.5 to 1 inch when the load is applied at three test points: 3.5 ft, 3.75 ft, and 4.0 ft from the exterior wall. Special attention is given to the stiffness and strength of this member due to its exposed position and the applied loading condition. The location of the Beam Deflection Test is determined on Construction Day.

2.3.3 Load Path

To ensure structural stability, all loads (gravity, lateral, and point) must be transferred safely from their point of application through the framing system to the foundation. This concept, known as the continuous load path, means that there can be no gaps or failures in the load transfer mechanism. Vertical loads are carried down through floor framing, walls, and footings, while lateral loads are transferred through diaphragms and shear walls. [1] All connections along these paths must be properly designed to handle anticipated forces without rupture, slippage, or deformation.

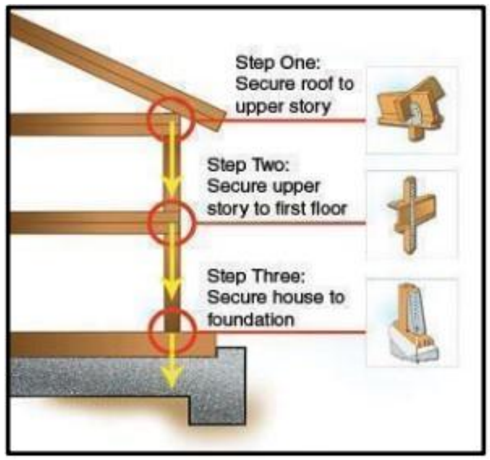

FIGURE 2: CONTINUOUS LOAD PATH (PATH FOR GRAVITY LOADS) [1]

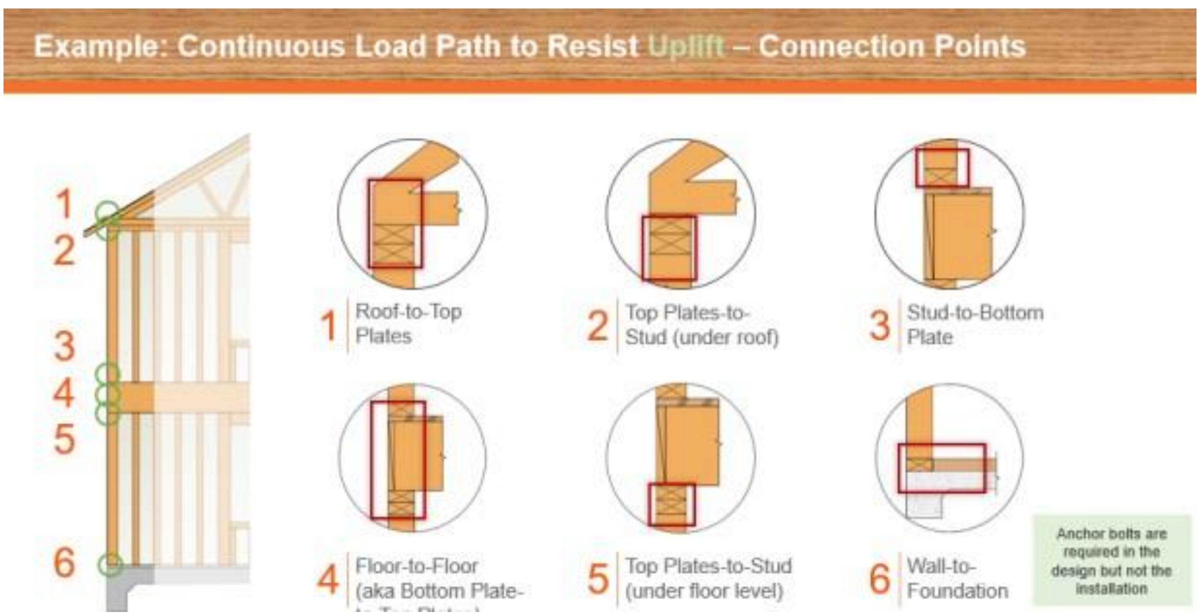

FIGURE 3: CONTINUOUS LOAD PATH TO RESIST IN UPLIFT [1]

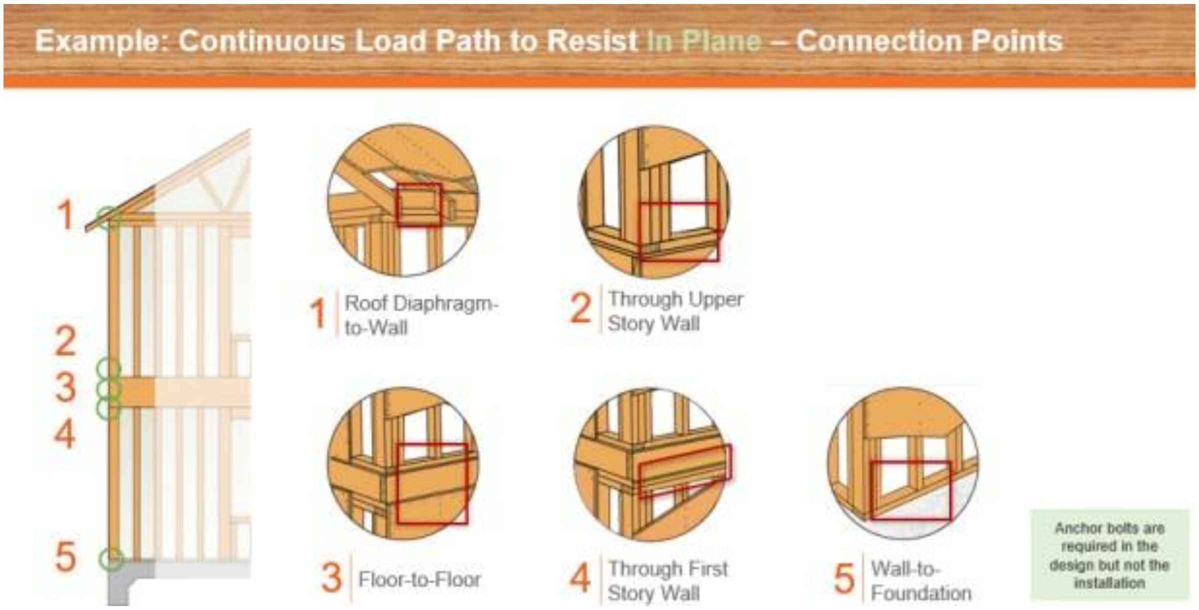

FIGURE 4: CONTINUOUS LOAD PATH TO RESIST IN PLANE [1]

Figure 3, Figure 4, and Figure 5 above may be found in the ASCE TimberStrong 2025 Rulebook. [1] A major focus of the competition stems from the implementation of the continuous load path in both the structure's design and modeling.

2.3.4 Design Criteria

The structural system must meet several design criteria based on strength and serviceability:

- **Gravity Loads**: Beams and columns must be checked for bending, shear, and axial stresses. Allowable stress design (ASD) methods are used, with factors of safety applied per code guidelines.
- **Lateral Loads**: Diaphragms and shear walls must resist in-plane shear and bending. Drift must remain within acceptable limits to avoid excessive deformation or instability.
- **Concentrated Load**: The cantilevered beam must limit deflection to between 0.5–1 inch under the 150 lb test load, tested at three different positions. Location of Beam Deflection Test is determined on Construction Day. [1]
- **Deflection Criteria**:
  - Beams and joists: L/240 for live load, L/180 for total load.
  - Columns: Limit lateral deflection to prevent instability.
  - Drift (story-level lateral displacement): Should not exceed 0.25 inches.
  - Cantilever beam: Deflection must be within 0.5–1 inch during test loading, as specified in competition rules. [1]

2.4 Construction Rules

Teams have 90 minutes to build a structure, following strict safety, material, and procedural guidelines. Each team is assigned an 18 foot by 18 foot site, where all materials and tools must remain. The structure cannot be anchored, and stability must be incorporated into the design. Pre-assembled roof panels must not exceed 30 lbs. or 12 inches in the narrowest dimension. Roof sheathing is attached on-site.

Construction begins only after the official signal from the judge, with all builders raising their hands and the team captain confirming readiness. The build order is: first-floor walls, second-floor framing, second-floor walls, and roof framing. Upon completion, all tools must be set down, and the team captain signals the judges to stop the timer.

Safety is the highest priority; builders must wear hard hats, safety glasses, gloves, closed-toe shoes, long pants, and high-visibility gear. Ladder safety training is required.

After completion, a cantilever floor beam deflection test is conducted as described in Section 2.3.

Violations result in penalties or disqualification, depending on severity. Judges have final authority on all rule enforcement and scoring and may halt construction for safety violations.

2.5 Scoring

The competition scoring is based on four main categories—Report, Visual Documentation and BIM, Presentation, and Construction—totaling 420 points, with up to 5 bonus points for build time. Judges evaluate teams on structural integrity, sustainability, creativity, and execution accuracy. The Report phase (130 pts) includes structural analysis, sustainability, budgeting, and report quality. The Visuals/BIM phase (150 pts) assesses visual aids, aesthetics, BIM model accuracy, and construction drawings. The Presentation (10 pts) focuses on clarity, technical content, and team participation. The Construction phase (130 pts + bonus) scores build accuracy, quality, compliance, and speed. Refer to Table 5 below for major point system. Full scoring details are available in the Competition Scoring Table (Appendix B).

TABLE 5: COMPETITION POINTS POSSIBLE

	Maximum Points
Phase 1: Report	130
Phase 2: Drawings, BIM, Visual Aid, Graphics	150
Phase 3: Presentation	10
Build Day: Construction	130 (+5 Bonus Points)
Total Points Possible	**420 (+5 Bonus Points)**

3.0 Preliminary Design and Analysis

3.1 Timber Species Decision Matrix

The decide what lumber was most appropriate to use for the project. A decision matrix was made using two key criteria, cost and availability. These two criteria were picked because they best fit the practical needs for the team, some of the lumber needed to be purchased with our strict budget and the rest was donated from a local business. Majority of the lumber that was donated was Hem Fir, making the availability factor the most significant.

Each type of timber was scored on a scale of one to three. One represents the least favorable and three being the most favorable performance in the criteria. The two criteria were weighted to show how important it was to the project; availability was the most important with 70% and the cost with 30%.

Below in the table you can see that Hem Fir has the highest grade and why it was chosen for the final design.

TABLE 6: TIMBER TYPE DECISION MATRIX

Timber Type Decsion Matrix		Douglas Fir		Southern Pine		Douglas Fir Larch		Hem Fir		Spruce Pine Fir	
Criteria	Weight (%)	Score	Weighted Grade	Score	Weighted Grade	Score	Weighted Grade	Score	Weighted Grade	Score	Weighted Grade
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		2		1		2.7		2.3

The result of the decision matrix shows that Hem Fir scored the highest overall, with it being the most available because it was donated, and the cost is relatively low. Spruce Pine Fir ranked well in both categories, but because it was not the species donated it was ranked lower on availability. Southern pine was readily available at the local stores and is lower cost, but it fell short because it was not donated. Douglas Fir and Douglas Fir Larch were good options but they are more expensive and not as readily available in Flagstaff, making them the least practical for this project.

The analysis confirms that Hem Fir is the best species of lumber for this project, it balances both the budget constraints and material accessibility.

3.2 Design Decision Matrix

Using a decision matrix, three different roof designs were evaluated based on six different criteria: structural integrity, cost, constructability, aesthetics, functionality, and sustainability. Different weights were assigned to each area of criteria according to its importance for our design. Structural integrity, aesthetics, and constructability have the highest weight, because they are the most critical factors, they are weighted at 30% and 20%. The structural integrity is the highest percent, it is making sure the design can withstand the loads given by competition. Constructability of the structure is 20% and it is how easy and efficient it can be built. Aesthetics are weighted 20% and it is important because at competition is a big part of scoring. Other criteria like the cost, functionality, and sustainability still hold an importance on the project just not as much with their weights being 10%. Each design was scored on a scale of one to three. One represents the least favorable and three being the most favorable performance in the criteria.

Below you can see the three different rood design alternatives the team designed.

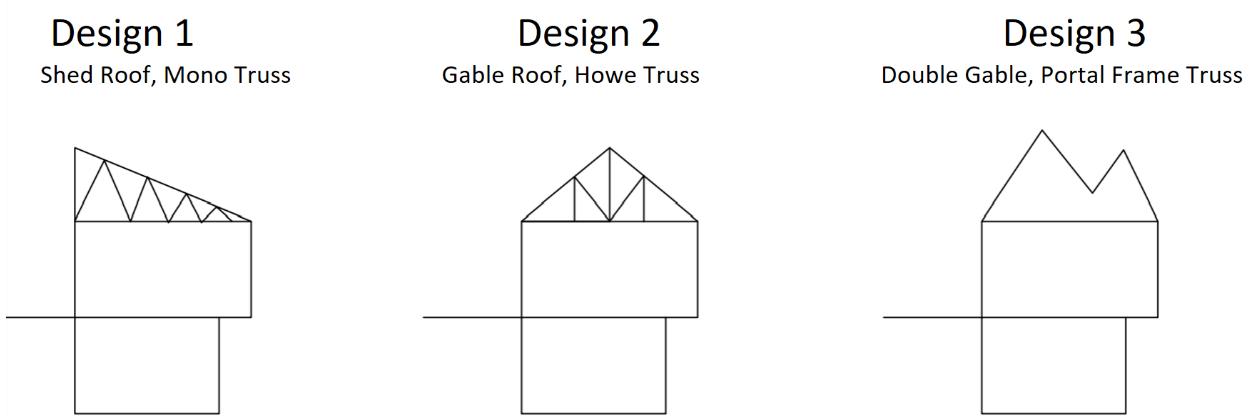

FIGURE 5: DESIGN ALTERNATIVES

Below in the table is the decision matrix showing the scores of each design alternatives under each criterion, it ultimately shows design 3 is the best alternative.

TABLE 7: DESIGN ALTERNATIVE 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

Each design alternative was evaluated based on six weighted criteria to determine the most suitable option for the project.

For structural integrity (30%), design 2 scored the highest, it has a strong, efficient, and basic layout. Design 1 scored slightly lower; it is adequate but not as strong compared to design 2. Lastly design 3 scored the lowest because it is a complex design and requires more structural support with the double peaks.

For cost (10%) design 1 and 2 scored the same, they have similar lumber needs making them very comparable. Design 3 scored lower because the design is complex and has additional lumber needed.

For the constructability (20%) design 2 scored the highest it is a straightforward, and easy to assembly and design. Design 1 and 3 scored lower because they are a little more complex with their unique features that add to the challenges in construction.

The aesthetic appeal (20%) of design 3 made it score the highest, the double peaks resemble the San Francisco peak make it unique. Design 1 scored the next highest for the clean look, and design 2 scored the lowest because it was the most basic and common look.

The functionality (10%) in design 2 scored the highest because of it sustainability and basic layout. Design 1 and 3 scored a little lower because of the more complex layout and how the space was used.

The sustainability (10%) in design 3 scored the highest because of its efficient use of materials. In design 1 and 2 they still have sustainable aspects but a little less than design 3.

Based on the decision matrix above, design 3 scored the highest under the criteria with a score of 2.4, therefore it is the most suitable for this project. It scored the lowest in structural integrity and cost, it outperformed in other areas that align with the competition priorities.

4.0 Final Design and Analysis

4.1 Roof Design

The roof was designed for gravity loading based on the provided loadings plus the deadweight. For the gravity design, three members were designed by finding the minimum required depth of member given the loading. Maximum axial loading, shear, and flexure were solved for as seen in Appendix C. These members consist of a rafter, a ridge beam, and a ridge beam stud. To be conservative, the members that experienced the greatest maximum axial, shear, and flexure values were used to size all roof members. Figure 7, below, shows where each one of these members is in the roof system. Table 5, below, summarizes the roof design calculations.

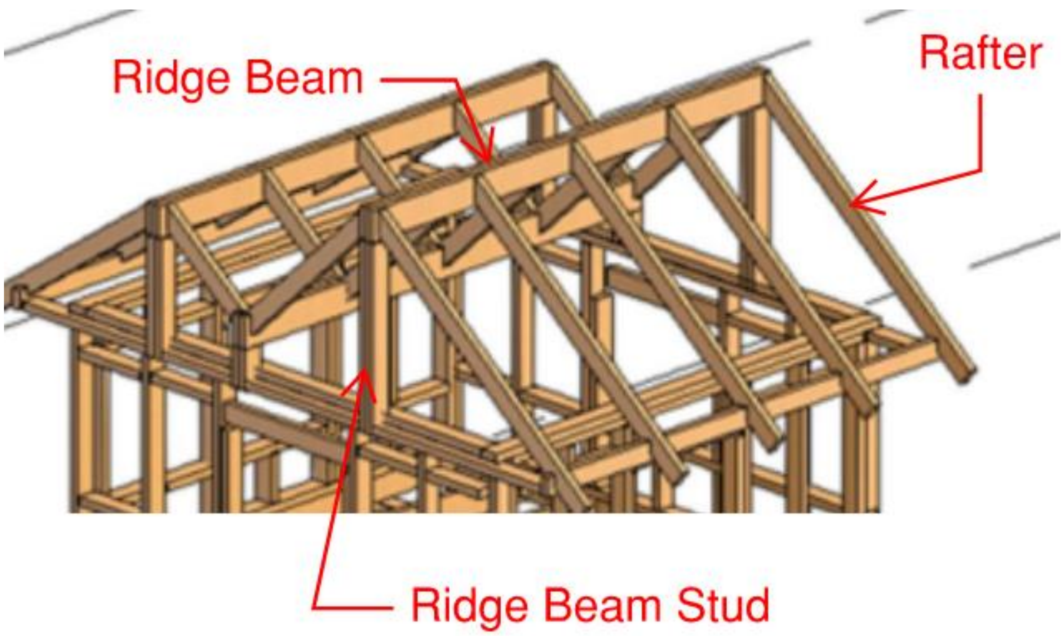

FIGURE 6: ROOF MEMBERS

TABLE 8: ROOF DESIGN SUMMARY

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

As seen in Table 5 above, the minimum required depths of each member were found, and an appropriate depth member was chosen. A factor of safety was also found for each member.

4.2 Wall Design

The walls were designed first with a base layout using common building practices such as placing studs 16 inches on center. Once a preliminary design was made, members were sized for their minimum required depths according to the loads endured by the respective members. Three distinct members were sized for each wall; the headers, jack studs, and king studs. The headers were designed for shear and flexure, and studs were designed for compression. A diagram showing where these members are within the walls can be seen below in Figure 8.

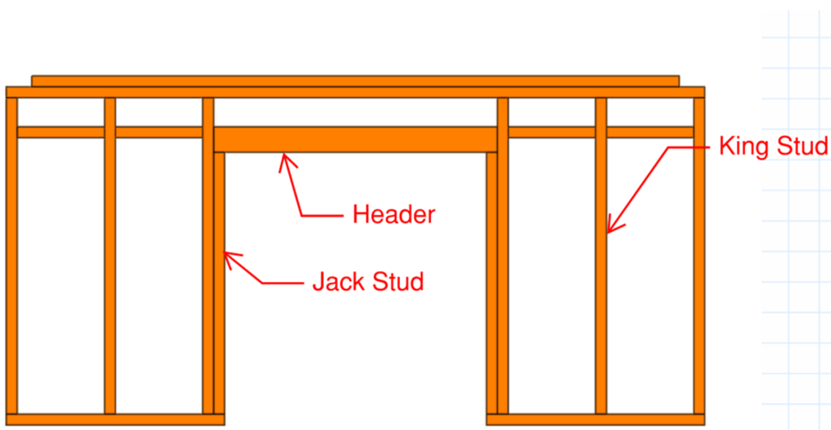

FIGURE 8: WALL MEMBER DIAGRAM – 1ST STORY NORTH WALL

In order to be conservative in the walldesign, the respective members that endured the greatest loading for each wall were chosen to design for. Appendix C shows the calculations performed in depth, and the results of one of the wall calculations are summarized below in Table 6.

TABLE 9: WALL DESIGN SUMMARY – 1ST STORY NORTH WALL

Wall Gravity Design - 1st Floor North Wall

Member	Required Force			Required Depth (in)	Provided Depth (in)	Factor of Safety
	Axial (lbs)	Shear (lbs)	Moment (lb*ft)			
Header	-	3.6	2.92	0.332	3.5	3.25
Jack Stud	3.6	-	-	0.001	3.5	59.16
King Stud	1147.44	-	-	0.41	3.5	2.92

As seen above, the minimum required depth was determined for each member based on the required force, an appropriate depth was chosen, and a factor of safety was calculated for each member.

4.3 Floor Design

The floor was designed to withstand gravity loading, which included the self-weight of the floor and the floor live load, as well as the self-weight of the second story walls and roof, and the roof live loading. A preliminary sketch of the floor was made, and the geometries from this were used to size the floor joists. The joists that were designed are shown below in figure 12.

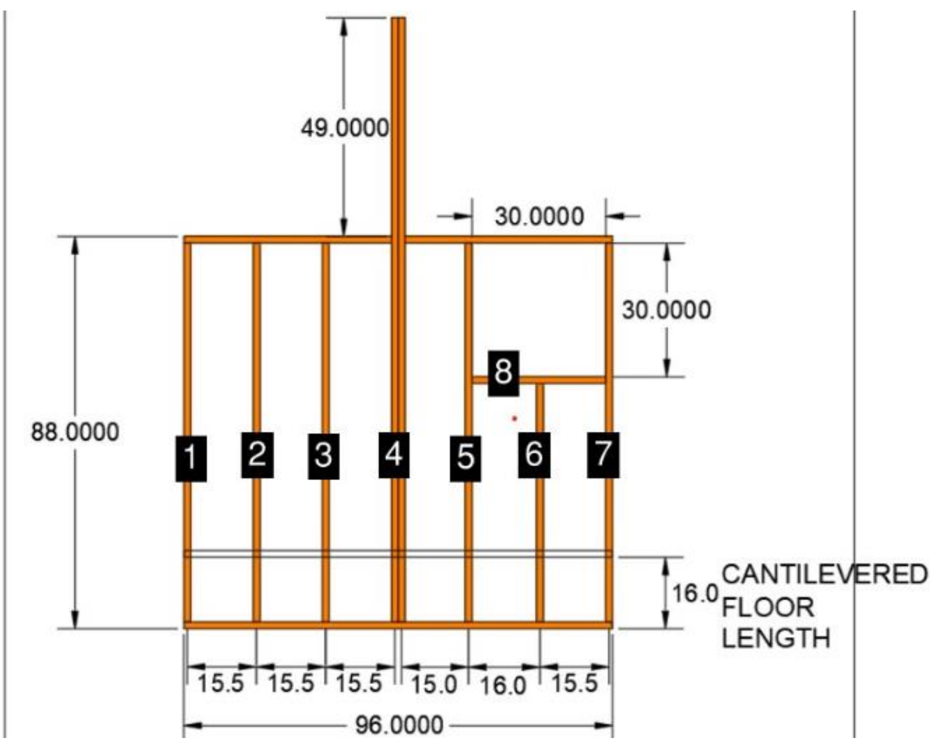

FIGURE 7:FLOOR JOISTS

As seen in Figure 12 above, each numbered member represents a joist. For each joist, the maximum shear and maximum flexure value were found, and a minimum required depth was calculated. A full breakdown of these calculations can be found in Appendix C. Table 7, shown below, summarizes the results of the floor calculations using the worst-case joist.

TABLE 10: FLOOR DESIGN SUMMARY

Floor Gravity Design					
Member	Maximum Shear (lb)	Maximum Moment (lb*f)	Required Depth (in)	Provided Depth (in)	Factor of Safety
Beam 5	472.1	8261.72	4.75	5.5	1.08

4.4 Cantilever Deflection

FIGURE 8: POINT LOAD CANTILEVER DEFLECTION [8]

Figure 2 above shows NAU's 2022 ASCE TimberStrong team next to their point load cantilevered deflection test. The cantilevered beam was designed to take its share of the floor loading as a distributed load, as well as a point load of 150 pounds at 3'6', 3'9", and 4'0". To design the cantilevered beam for the appropriate deflection, a preliminary design of 2 nominal 2x4's was used. A shear and moment diagram were made for this beam, and the maximum shear and moment values were found to verify that nominal 2x4 would work. After this, the method of sections and the double integral method was used to solve the deflection of the beam at the end. The results of this are summarized in the table below, and a full breakdown of these calculations can be found in Appendix C.

TABLE 11: CANTILEVERED BEAM DEFLECTION VALUES

Loading Point	Deflection (in)
4’0”	0.62
3’9”	0.53
3’6”	0.50

4.5 Diaphragms and Shear Wall Factor of Safety

The roof and floor diaphragms were designed using the SPDWS. The loads applied to the diaphragms are the given lateral seismic loading, and are applied in both directions, however not simultaneously. For the sake of simplicity for the competition, the diaphragms were designed as flat rectangles. Utilizing the geometries of the diaphragms, the maximum shear was solved for in both directions. To design both the chords and the collectors, the maximum stress due to tension was found, and was compared to the allowable stress in the specific member. In order to calculate the factor of safety for each of the diaphragms in both directions, the allowable shear force was divided by the maximum shear force experienced by the diaphragm. The allowable shear force in the diaphragms were found from Table 4.2A in the SDPWS, and were based upon sheathing size, nail size, and nail spacing. From this, an adjusted allowable shear force was found utilizing the NDS. The diaphragm factors of safety are summarized in the table below.

TABLE 12: DIAPHRAGM FACTOR OF SAFETY

Type	Factor of Safety
Roof	2.05
Floor	2.33
Average	2.12

To design the shear walls, the maximum shear values found in the diaphragms was applied as the loading. For every wall besides the first story North wall, the Force Transfer Around Opening Method was used. This method involved finding the FTAO adjusted shear by dividing the maximum shear value by the perimeter of the opening. From this, the required shear value was compared to the allowable shear values given by Table 4.2A in the SDPWS. The first story North wall had to be designed using the segmented method due to the door opening. This method involved breaking the wall up into sections not including the opening in order to find the required shear capacity. To calculate the factors of safety in the shar walls, the adjusted allowable shear values were divided by the required shear values. These results are summarized in the table below.

TABLE 13: SHEAR WALL FACTOR OF SAFETY

Type	Factor of Safety
First Story	1.91
Second Story	1.57
Average	1.77

Tables 11 and 12, below, summarize the calculations done to design both the diaphragms as well as the shear walls. The detailed calculations can be found in Appendix C.

TABLE 14: DIAPHRAGM DESIGN

Diaphragm Design					
Component		**Required Force**	**Allowable Force**	**Target Factor of Safety**	**Factor of Safety**
Roof	Sheathing	131.25 plf	187.84 plf	1.5	1.43
	Chord	62.5 psi	1864.58 psi		
	Collector	183.33 psi	1864.58 psi		
Floor	Sheathing	133.81 plf	187.84 plf	1.5	1.4
	Chord	32.44 psi	1868.58 psi		
	Collector	76.36 psi	1868.85 psi		

TABLE 15: SHEAR WALL DESIGN

Shear Wall Design - 2nd Story East/West Walls				
Component	**Required Force**	**Allowable Force**	**Target Factor of Safety**	**Factor of Safety**

Sheathing	96.8 plf	145.79 plf	1.5	1.51
Horizontal Strap	283.35 lb	1235 lb		
Vertical Strap	602.78 lb	1235 lb		

5.0 Modeling and Competition Presentation

5.1 Two Dimensional Modeling

The structural design portion of the project includes a comprehensive set of two dimensional drawings to accurately show the structural and constructability of the two-story structure. The drawings are important for showing key elements of the structure like the framing plans, shear wall connections, diaphragm sheathing layouts, and the continuous load path. The drawings will also detail the anchorage and connectors to ensure the structural integrity under gravity, wind, and seismic loads. In the table below it shows an overview of the structural drawing's requirements for the competition.

TABLE 16: STRUCTURAL DRAWING REQUIREMENTS

Category	Requirement Description
Framing Plans	Detailed 2d framing plan for first and second floor, include member size and the layout
Shear Wall Connection Details	Detail of all shear wall connections: hold downs, anchor bolts, and hardware types
Panelized Diaphragm and Sheathing	Type of diaphragm and shear wall sheathing type, nail patterns, and fastening schedules
Connectors, Blocking and Fasteners	The type of Simpson Strong Tie connectors, location of blocking, fastener sizes and patterns
Continuous Load Path	Plan views, elevations, and cross section views
Anchorage to Foundation	Detail of how it will be anchored include the SST hold downs and ½" anchor bolts

In Appendix D there are complete structural drawings. In the figure below is an example of the AutoCAD 2D modeling.

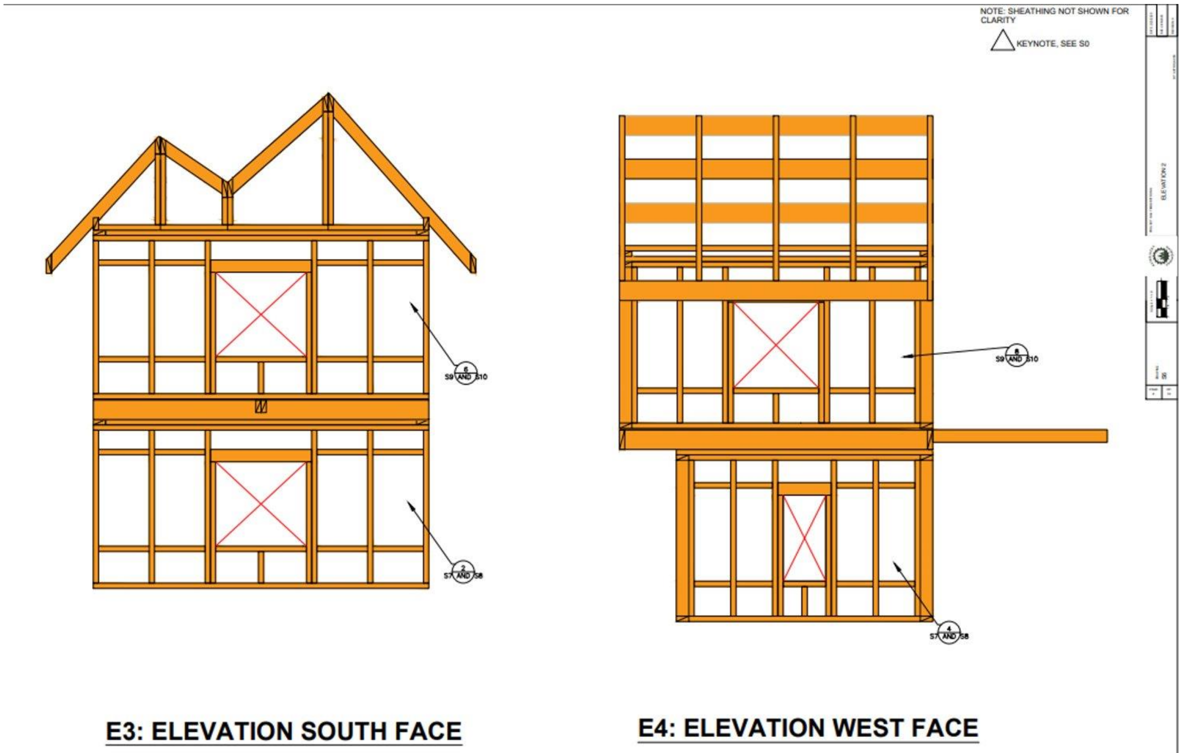

FIGURE 9: AUTOCAD DRAWING

5.2 Three Dimensional Modeling

The Building Information Model (BIM) component of the project is important to have visual representation of the structure in three dimensional and verify constructability. The model must have a complete and accurate load path, all framing members, connectors, and fasteners. In Revit and using the Simpson Strong Tie plugin, the model must show accurate material quantities and cost estimates. The table below shows the key requirements for the three dimensional modeling for the competition.

TABLE 17: MODELING REQUIREMENTS

Category	Requirement Description

Software	Created in Revit (rvt. Format)
Structural Components	Framing members, walls, floors, roof, and openings
Connectors and Fasteners	Simpson Strong Tie Plugin to model real connectors
Load Path	Show gravity, wind, and seismic load paths continuously through the roof to foundation
Sheathing and Fastening	Diaphragm/shear wall sheathing and fasteners
Cantilever Beam	Accurate beam size, span, anchorage, and point load (locations)
Renderings and Views	Multiple three-dimensional views

In the figures below you can see the back view and side view of our three-dimensional modeling in Revit. The side view has a silhouette at 6' for reference.

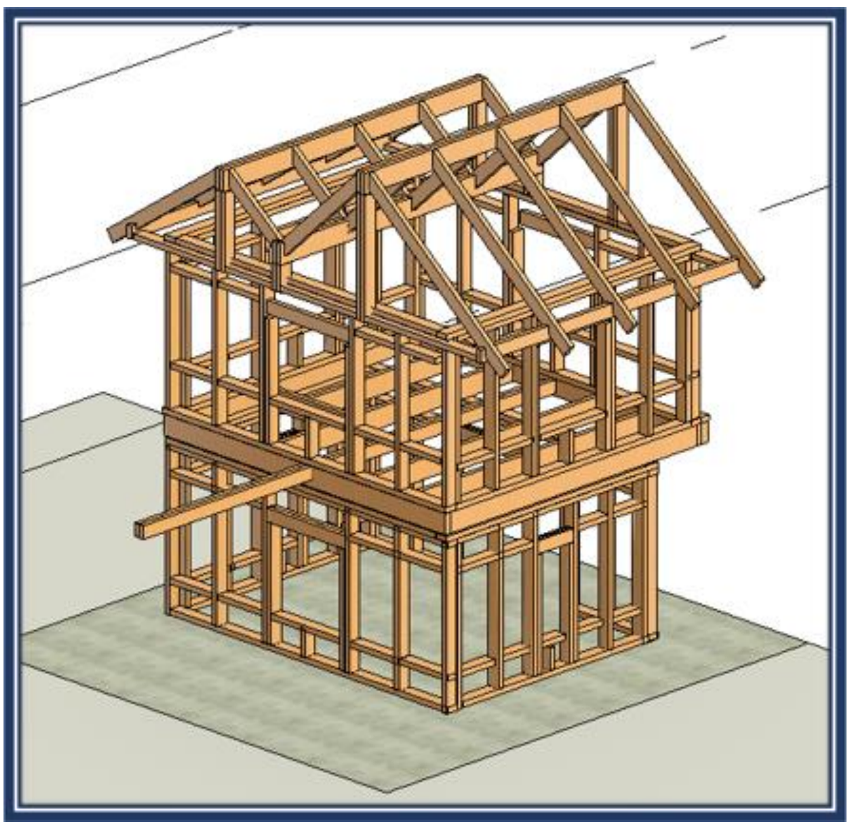

FIGURE 10: REVIT BACK VIEW

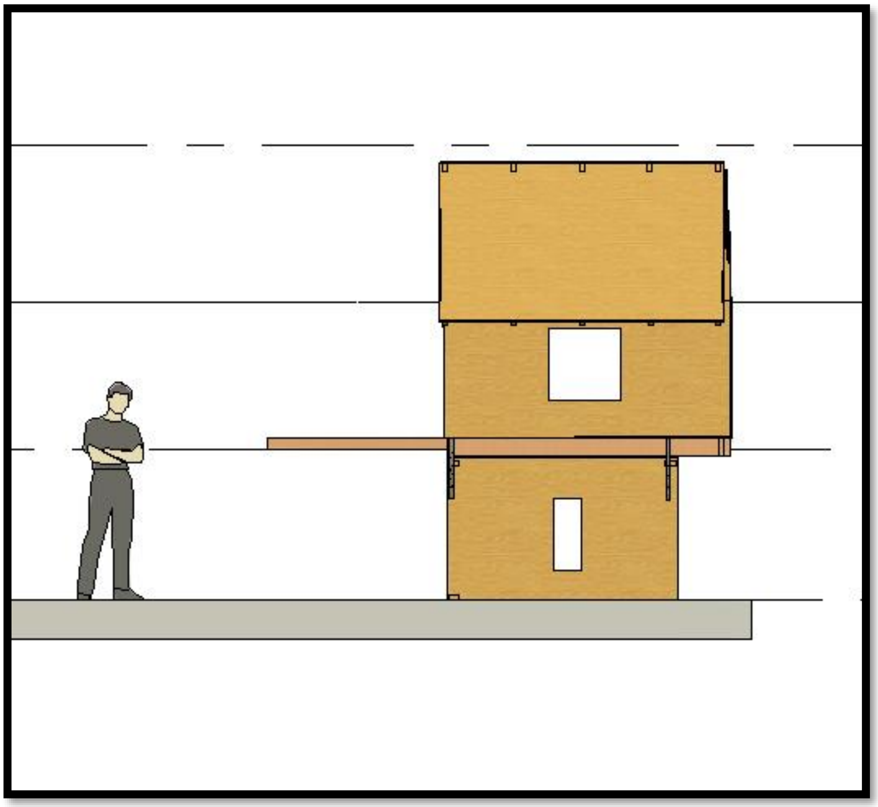

FIGURE 11: REVIT SIDE VIEW

5.3 ASCE Presentation and Visual Aid

Phase 3 submittal for the competition was the formal presentation and visual aid of the project that showed the design and analysis of the project. The required components are shown in the table below.

TABLE 18: PRESENTATION AND VISUAL AID REQUIREMENTS

Content Required
Name of all team builders and student chapter name
Design Features
Graphics and snapshots of the structure
A table indicating the calculated cantilever beam deflections and bearing force per linear foot of the sill plate of the wall opposite the cantilever beam for each of the three possible point load locations
Shear wall and diaphragms factors of safety
Carbon footprint analysis result
Total weight of the entire structure
Total material costs of the structure
Sponsor logos (ASCE, AWC, APA, and Simpson Strong Tie)

The final presentation poster shows the required criteria from the table above in a clear organized format that you can see below.

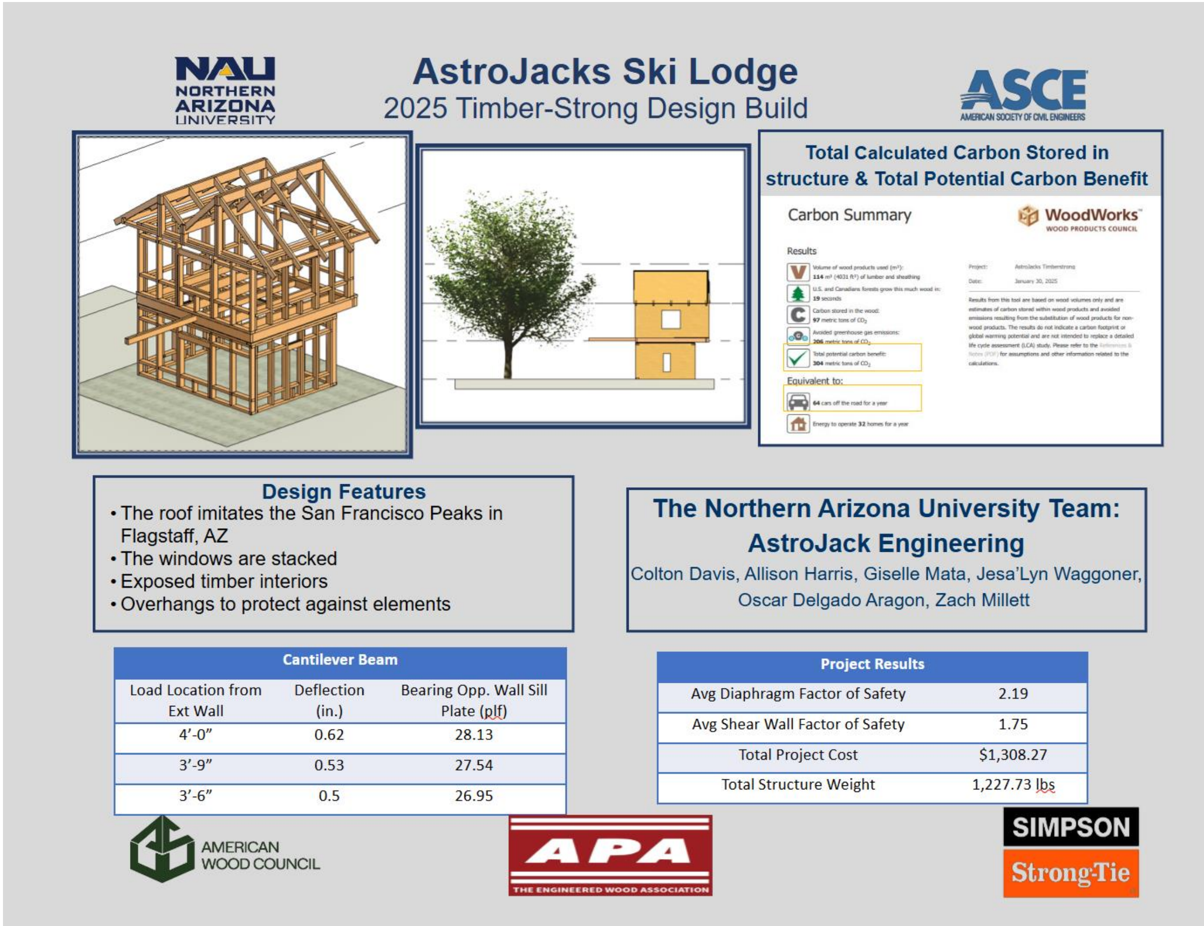

FIGURE 12: COMPETITION VISUAL AID

6.0 Design Implementation

6.1 Construction

6.1.1 Material Acquirement

The lumber was donated from HomCo and was stored at the field station. Any additional lumber we needed we purchased from HomCo and Home Depot. All connectors and fasteners were donated from Simpson Strong Tie, and the building tools are all available at the field station. In the figure below you can see the team going through the donated wood to look for the most intact and least warped pieces.

Figure 13: Going Through Lumber

6.1.2 Prefabrication

To help speed up construction time during the competition, the team prefabricated the structural components at the NAU Field Station. The team assembled the walls, sections of the roof, the floor and pre-marked the fastening locations. We organized and labelled each section for quick assembly. In the figure below you can see the team putting together sections of the structure.

FIGURE 14: PREFABRICATION

In the figure below you can see the wall put together for prefabrication.

FIGURE 15: WALL PREFABRICATED

6.1.3 Construction Practice

The multiple trials of building were done prior to the competition to familiarize the team and the mentees. Practicing allowed the team to figure out the construction sequence, refine the workflow, and identify potential issues with fittings. The timed assemblies allow the team to improve efficiency under pressure and ensure it could be built within 90 minutes. In the figure below you can see the structure (minus the roof sheathing and hardware) put together after one of the times practicing.

FIGURE 16: PRACTICE BUILD

6.1.4 Competition Build Day

On competition build day the team was able to execute the build smoothly thanks to preparation and practice beforehand. Each member was assigned a task and role throughout construction. The prefabricated elements were set up to ease and speed up the construction. All elements were quickly assembled, and all connections were secured according to plans. The team was able to complete the construction in 65 minutes, well within the 90 minute window and then presented to the judges. In the figure below you can see the entire structure built at competition.

FIGURE 17: COMPETITION BUILD DAY

In the figure below you can see the cantilever beam being loaded at competition

FIGURE 18: CANTILEVER BEAM LOADING

6.2 Competition Result

The team earned 1st place over in the ASCE 2025 TimberStrong Design Build competition, because of our excellent structural design, execution, and presentation. Also, the team was awarded 1st place in the Building Information Modeling (BIM) category recognizing the precision and clarity of the modeling submission. The clean sweep of the competition categories shows the team's dedication excel in both the technical and practical areas of the project. In the list below you can see the breakdown of scoring for each submission, and in Appendix E you can see full score sheet.

Individual Submission Points

- Phase 1: Report: 98.5 out of 130 points
- Phase 2: Drawings, BIM Model, Visual Aids, Graphics: 133.5 out of 150 points
- Phase 3: Presentation: 9 out of 10 points
- Build Day: 111 out of 130 points

Overall Points

- NAU's total score across all phases is 352.5 out of 420 points.

In the photo below you can see the team all together with their winning awards after the ASCE banquet.

FIGURE 19: AWARD BANQUET

7.0 Deconstruction

After the competition is over, the team will carefully disassemble to structure in reverse order of its construction. This method will ensure efficiency and will minimize the damage to the structure. After it is completed disassembled, the structures pieces will be transported back to the NAU FARM to be stored until needed.

The structure will then be donated to a NAU professor, he will be repurposing it has a chicken coop and a rabbit hutch. This aligns with our team’s sustainability efforts and with the donation it will extend the life cycle of the materials.

8.0 Summary of Engineering Work

8.1 Schedule Overview

The TimberStrong Design Build capstone project began Septemner3, 2024 and was completed on May 6, 2025, for a total of 175 weekdays. The project’s timeline aligned with ASCE rules, university breaks, and academic deadlines. The detailed Gantt chart is Appendix F and shows the entire project timeline. Some keys phases of the project include conceptual design, structural analysis, BIM modeling, report development, construction preparation, and competition execution. Some of the key aspects of CENE 486C included 30%, 60%, and 90% submittals, final presentation, team website, and a final report. TimberStrong competition deliverables include design narrative, BIM model, in person build, presentation, and visual display.

8.2 Schedule Changes

All milestones and deliverables were completed on schedule. There were no changed to the prosed schedule or scope, everything proceeded according to the original timeline.

9.0 Summary of Engineering Costs

9.1 Staffing Matrix

In the table below, it shows the distribution of hours worked across the project tasks and the members of the team, it shows a comparison of the actual hours compared to the total initial estimates. In total the team recorded 765 hours, this is over the proposed 726 hours. The increase in hours was observed across multiple tasks, especially in the design and construction aspects of the project. These phases required more detail and time than we expected. Overall, even though hours varied across tasks than expected, there were no changes to the original scope. These unexpected time challenges show how dedication the team was to the final product ultimately contributed to our success and award winning final product.

TABLE 19: STAFFING MATRIX

Position	SENG	STENG	SUPR	SAFT	INT	Total	Proposed
Task 1 Background Research	10	26	3	3	4	46	49
Task 2 Preliminary Design	25	60	10	10	4	109	116
Task 3 Design and Analysis	10	15	0	2	6	33	41
Task 4 Roof Design	30	65	2	5	5	107	84
Task 5 Wall Design	30	40	5	5	4	84	74
Task 6 Modeling	15	20	4	0	2	41	36
Task 7 Construction	10	20	65	50	30	175	175
Task 8 Deconstruction Plan	0	1	2	2	4	9	10
Task 9 Investigate Project Impacts	3	6	2	1	3	15	15
Task 10 Project Deliverables	25	45	11	8	2	91	81
Task 11 Project Management	15	15	15	10	0	55	45
Total	173	313	119	96	64	765	
Proposed	153	313	115	100	45		726

9.2 Cost Overview

The overall cost of engineering services for this project included personnel, travel, lab usage, and construction materials. The personnel hours were tracked throughout the whole project and the cost were calculated using position specific hourly rates. were found on the US Department of Labor website and accounted for the roles of senior engineer, structural engineer, superintendent, safety officer, and engineering intern [9].

The travel expenses for the project included transportation to and from the competition site in Tucson, AZ. The rental vans were rented for 5 days and milage costs were included for a total of 500 miles round trip. In Tucson we were lodged for four nights in four rooms, and a per diem of $60 per day was included for food.

The lab usage expenses covered the cost for the prefabrication that was done at NAU’s Field Station over seven days, charged $100 per day. The material costs included lumber, OSB sheathing, fasteners, hardware, and paint. These were based on a local Flagstaff business HomCo [6].

The total estimated cost of the project was $144,110, the largest part of it was the personnel cost at $135,180. The breakdown of expenses shows a comprehensive, and realistic estimate of the resources needed to complete a successful and competition winning project.

TABLE 20: COST ESTIMATE

Description	Quantity	Unit of Measure	Rate $	Cost
Personnel				
Senior Engineer	153	Hr	$ 260.00	$ 39,780
Structural Engineer	313	Hr	$ 200.00	$ 62,600
Superintendent	115	Hr	$ 220.00	$ 25,300
Safety Officer	100	Hr	$ 75.00	$ 7,500
Engineering Intern	45	Hr	$ 20.00	$ 900
		Subtotal Personnel		$ 135,180
Travel				
Rental Van	5	Days	$ 73.54	$ 368
Driving Mileage	500	Miles	$ 0.41	$ 205
Per Diem	4	People ($60 per day for 5 days)	$ 300.00	$ 1,200
Hotel Room	4	Nights (4 rooms)	$ 1,200.00	$ 4,800
		Subtotal Travel		$ 6,573
Lab Use				
Field Station "Farm"	7	Days	$ 100.00	$ 700
		Subtotal Lab use		$ 700
Materials				
2x4x8 Hem Fir	70	EA	$ 5.78	$ 405
2x4x20 Hem Fir	4	EA	$ 7.33	$ 29
OSB Sheet (4x8)	18	EA	$ 23.36	$ 420
Fasteners	5	EA	$ 40.53	$ 203
Connectors / Hardware	1	LS	$ 1.00	$ 500
Paint	10	Gal	$ 10.00	$ 100
Primer	10	Gal	$ 20.00	$ 200
			Subtotal Material Cost	$ 1,657
		Total Cost of Engineering Services		**$ 144,110**

9.3 Cost Changes

The overall project cost increased by about $5,693 from the original estimate. The cost increases mainly from the extra hours worked by the senior engineer, superintendent, and the engineering intern. The material costs also varied from the proposed budget. The quality of the lumber increased, and adjustments were made during construction for the structural and framing needs. There was money saved because we anticipated higher costs for lumber and sheathing, but it came out cheaper. We also did not end up using any primer and getting a paint that had primer in it, this saved us money in the long run.

The final project cost ending up being $149,803, reflecting an increase of $5,698 from the original budget. The full cost breakdown is in the table below.

Table 21: Final Project Costs

Description	Quantity	Unit of Measure	Rate $	Cost
Personnel				
Senior Engineer	173	Hr	$ 260.00	$ 44,980
Structural Engineer	313	Hr	$ 200.00	$ 62,600
Superintendent	119	Hr	$ 220.00	$ 26,180
Safety Officer	96	Hr	$ 75.00	$ 7,200
Engineering Intern	64	Hr	$ 20.00	$ 1,280
		Subtotal Personnel		$ 140,960
Travel				
Rental Van	5	Days	$ 73.54	$ 368
Driving Mileage	500	Miles	$ 0.41	$ 205
Per Diem	4	People ($60 per day for 5 days)	$ 300.00	$ 1,200
Hotel Room	4	Nights (4 rooms)	$ 1,200.00	$ 4,800
		Subtotal Travel		$ 6,573
Lab Use				
Field Station "Farm"	7	Days	$ 100.00	$ 700
		Subtotal Lab use		$ 700
Materials				
2x4x8 Hem Fir	86	EA	$ 3.75	$ 323
2x4x20 Hem Fir	7	EA	$ 10.22	$ 72
OSB Sheet (4x8)	18	EA	$ 17.98	$ 324
Fasteners	5	EA	$ 40.53	$ 203
Connectors / Hardware	1	LS	$ 500.00	$ 500
Paint	5	Gal	$ 29.98	$ 150
Primer	0	Gal	$ 20.00	$ -
			Subtotal Material Cost	$ 1,570
			Total Cost of Engineering Services	**$ 149,803**

10.0 Project Impacts

Our project has made a significant contribution to reducing the carbon footprint and promoting sustainability. Using the WoodWorks Carbon Calculator, we estimated a total potential carbon benefit of 304 metric tons of CO_2 which is equivalent to taking 64 cars off the road or powering 32 homes for one year. This highlights the environmental advantage of using wood over light-gauge steel, which has a substantially higher embodied carbon due to its energy-intensive manufacturing process.

From a social perspective, our choice of wood supports the use of locally sourced materials, enhancing community resilience and promoting regional economies. Timber also provides a natural aesthetic that many find more inviting and homely compared to the modern but colder aesthetic of steel. However, wood can have a shorter lifespan and greater vulnerability to pests or weather extremes, potentially impacting long-term livability and maintenance.

Economically, our use of donated lumber significantly lowered initial material costs, a clear benefit over steel, which often involves higher material and labor costs due to the need for specialized installation. On the downside, timber may incur higher long-term maintenance expenses and might not retain resale value as well as a steel-structured home, which is typically more durable and fire-resistant.

In summary, compared to light-gauge steel studs, our timber structure offers clear environmental benefits and initial cost advantages, while also fostering a more natural, community-focused design. These benefits are balanced by potential trade-offs in long-term durability and maintenance, but overall, the choice of wood aligns strongly with sustainability goals across all three P's (People, Planet, and Profit).

11.0 Conclusion

TimberStrong Design Build extended the ASCE student teams the opportunity to participate in the 2025 Design-Build Competition, wherein competitors took on the roles of design-build firms to efficiently plan and execute a two-story, light-frame timber structure while balancing structural integrity, sustainability, architectural style, and constructability. Through effective teamwork, our team's refined engineering assessment, and adept project scheduling, we succeeded in meeting and exceeding all requirements set by the competition. Our capstone project incorporated advanced structural design features such as a cantilevered beam, and a dual-peak roof that was reminiscent of the San Francisco Peaks, framed windows arranged to optimize self-sustained lighting, and flooding the interior with natural light. With the BIM model and construction documents we created, along with our ensured accuracy, the build was completed in an impressive 65 minutes, far below the 90-minute maximum time limit. The build not only remained within specified timber design guidelines but also adhered to building standards that prioritize aesthetic appeal and environmental sustainability. Winning these awards underscored our design prowess alongside our seamless execution strategies at the competition; securing us the 1st place position and modeling accolades at the 2025 BIM competition.

References

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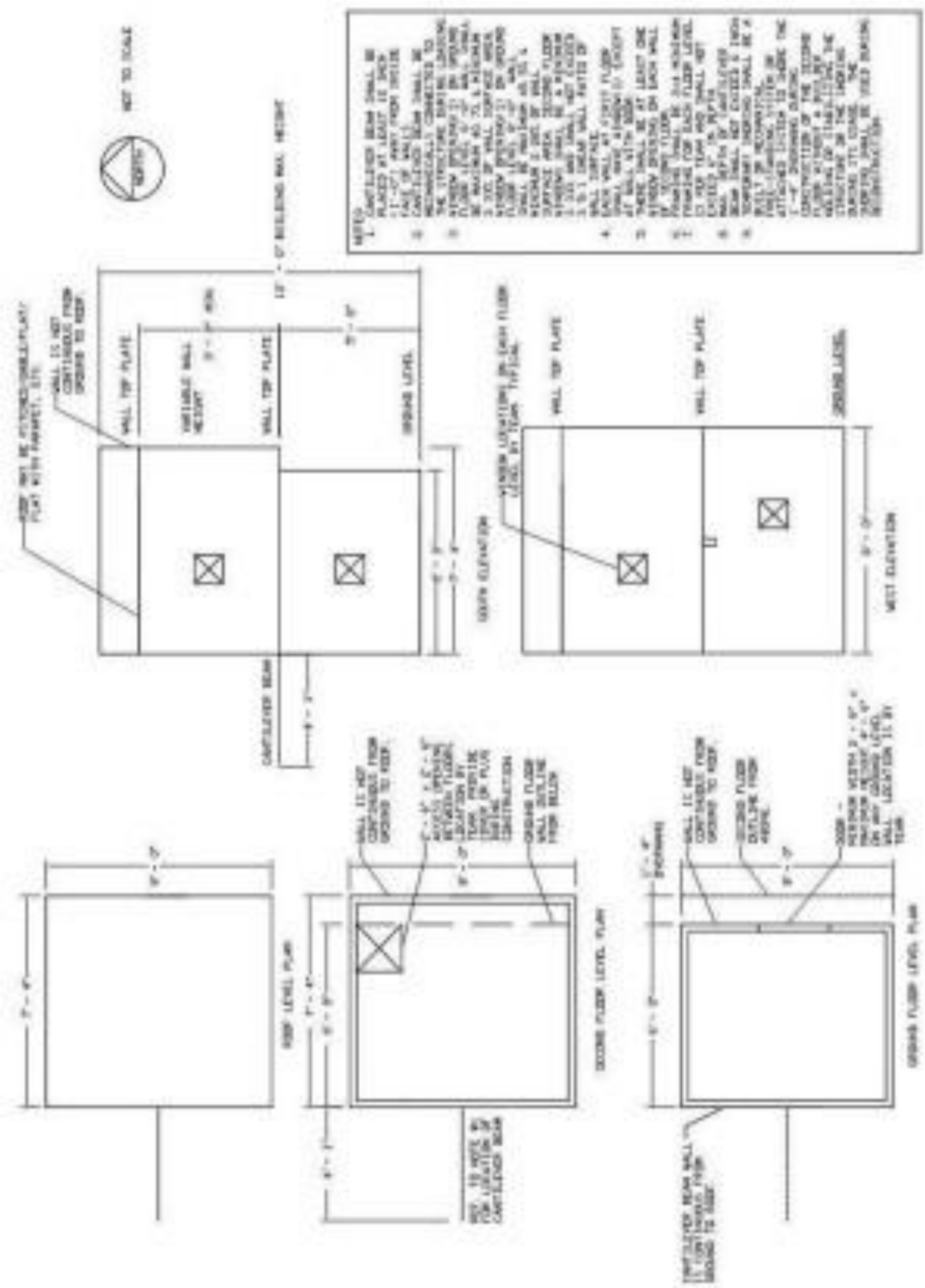
[7] “Wood for sustainable and biophilic building design”, WoodWorks. (2022, January 20). WoodWorks | Wood Products Council; WoodWorks - Wood Product Council. https://www.woodworks.org/why-wood/sustainability/

[8] Timber-Strong Design Build Competition. (n.d.). Asce.org. Retrieved March 23, 2025, from https://www.asce.org/communities/student-members/conferences/timber-strong-design-build-competition

[9] US Department of Labor, "Employment and Earnings By Occupation," 2021. [Online]. Available: https://www.dol.gov/agencies/wb/data/occupations. [Accessed 6 November 2023].

Appendices

Appendix A: Framing Envelope


NOT TO SCALE
SOUTH ELEVATION
WEST ELEVATION
ROOF LEVEL PLAN
SECOND FLOOR LEVEL PLAN
GROUND FLOOR LEVEL PLAN
CANTILEVER BEAM
WALL TOP PLATE
GRADE LEVEL

Appendix B: Competition Scoring Table

	Maximum Points
PHASE 1: REPORT	
Design Strength and Durability Analysis	82
Sustainable Design	18
Budget	20
Report Requirements	10
PHASE 2: DRAWINGS, BIM, VISUAL AID, GRAPHICS	
Visual Aid	10
Creativity & Aesthetics	20
BIM	70
Construction Drawings	50
PHASE 3: PRESENTATION	
Presentation	10
Design Points Possible	**290**
BUILD DAY: CONSTRUCTION	
Accuracy and Demonstration of Load Path	50
Quality, Aesthetics and Speed	60
Structure Requirements	20
Build Time (BONUS)	5
Construction Points Possible	**130 (+5 bonus points)**
TOTAL POINTS POSSIBLE	**420 (+5 bonus points)**

Appendix C: Calculations

Appendix D: Structural Drawings

Appendix E: Score Sheet

Appendix F: Gantt Chart