2023-2024 TimberStrong Design - Build

CENE 476 – December 8th, 2023

Jenna Hays

Mariah Boler

Mourtice Clitso

PONDEROSA TIMBERJACKS

1.0 PROJECT PURPOSE AND BACKGROUND

- Design and analyze a timber structure using:
  - Concepts of structural engineering
  - Timber design codes
- Create 2D and 3D models of the structure
- Construct and compete against other teams
  - ASCE Intermountain Southwest Student Symposium, April 2024
  - Logan, Utah – Utah State University (USU)
- Client: Mark Lamer

Figure 1: 2022 TimberStrong Structure [1]

2.0 SCOPE – TASK 1: Background Research

Task 1.1: Competition Rules

- Scoring and design constraints

Task 1.2: Material Research

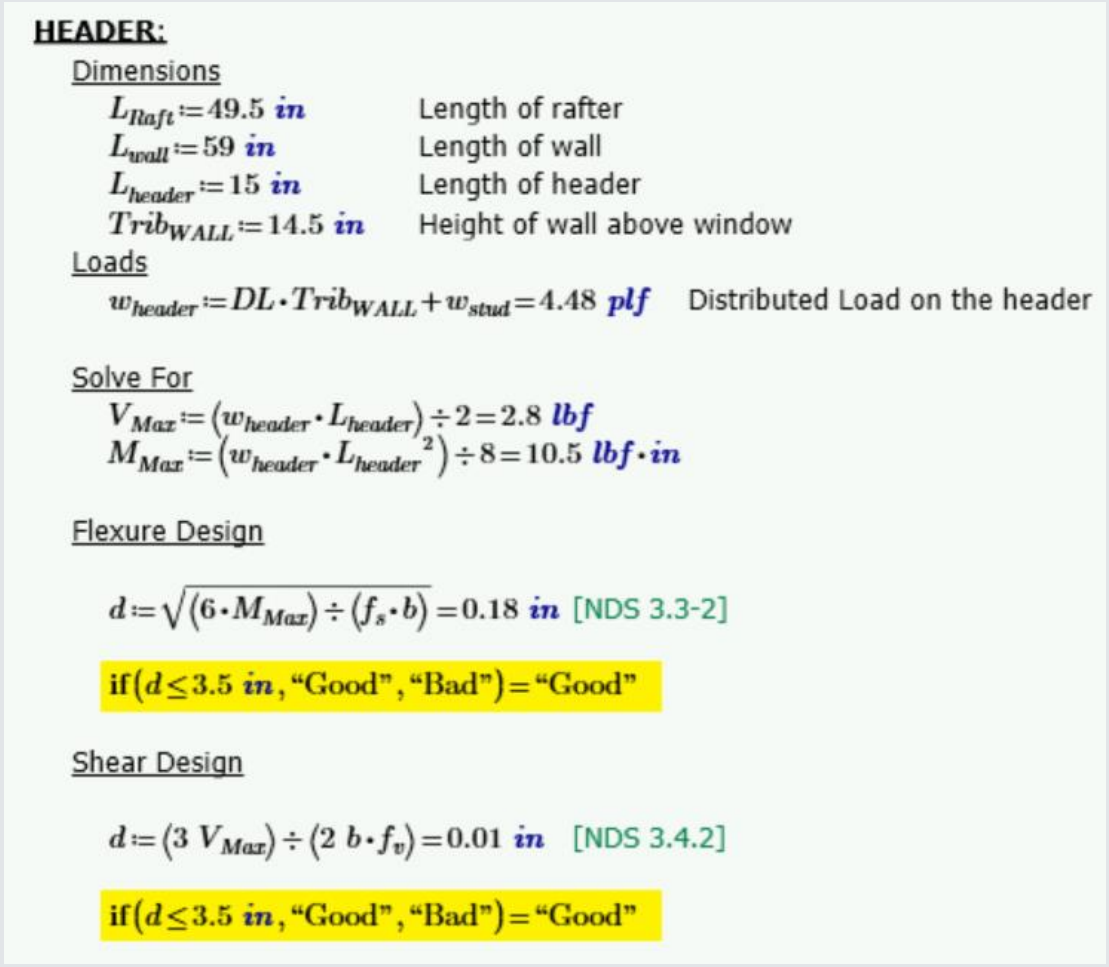
- Timber species and grade
- Fasteners

Task 1.3: Design Codes

- National Design Specification (NDS)
- NDS Supplement
- Special Design Provisions for Wind and Seismic (SDPWS)

Task 1.4: MathCAD Training

- Used to design and analyze the structure
- Utilized in other classes



HEADER:

Dimensions

$L_{Raft} := 49.5\ in$ Length of rafter
$L_{wall} := 59\ in$ Length of wall
$L_{header} := 15\ in$ Length of header
$Trib_{WALL} := 14.5\ in$ Height of wall above window

Loads

$w_{header} := DL \cdot Trib_{WALL} + w_{stud} = 4.48\ plf$ Distributed Load on the header

Solve For

$V_{Max} := \left(w_{header} \cdot L_{header}\right) \div 2 = 2.8\ lbf$
$M_{Max} := \left(w_{header} \cdot L_{header}^{2}\right) \div 8 = 10.5\ lbf \cdot in$

Flexure Design

$d := \sqrt{\left(6 \cdot M_{Max}\right) \div \left(f_s \cdot b\right)} = 0.18\ in$ [NDS 3.3-2]

$\text{if}\left(d \le 3.5\ in, \text{“Good”}, \text{“Bad”}\right) = \text{“Good”}$

Shear Design

$d := \left(3\ V_{Max}\right) \div \left(2\ b \cdot f_v\right) = 0.01\ in$ [NDS 3.4.2]

$\text{if}\left(d \le 3.5\ in, \text{“Good”}, \text{“Bad”}\right) = \text{“Good”}$

Figure 2: MathCAD Example [2]

2.0 SCOPE – TASK 2: Preliminary Design and Analysis

Task 2.1: Timber Decision Matrix

- Five possible timber species
- Softwood grades 1-5
- Matrix based on cost, availability, and strength

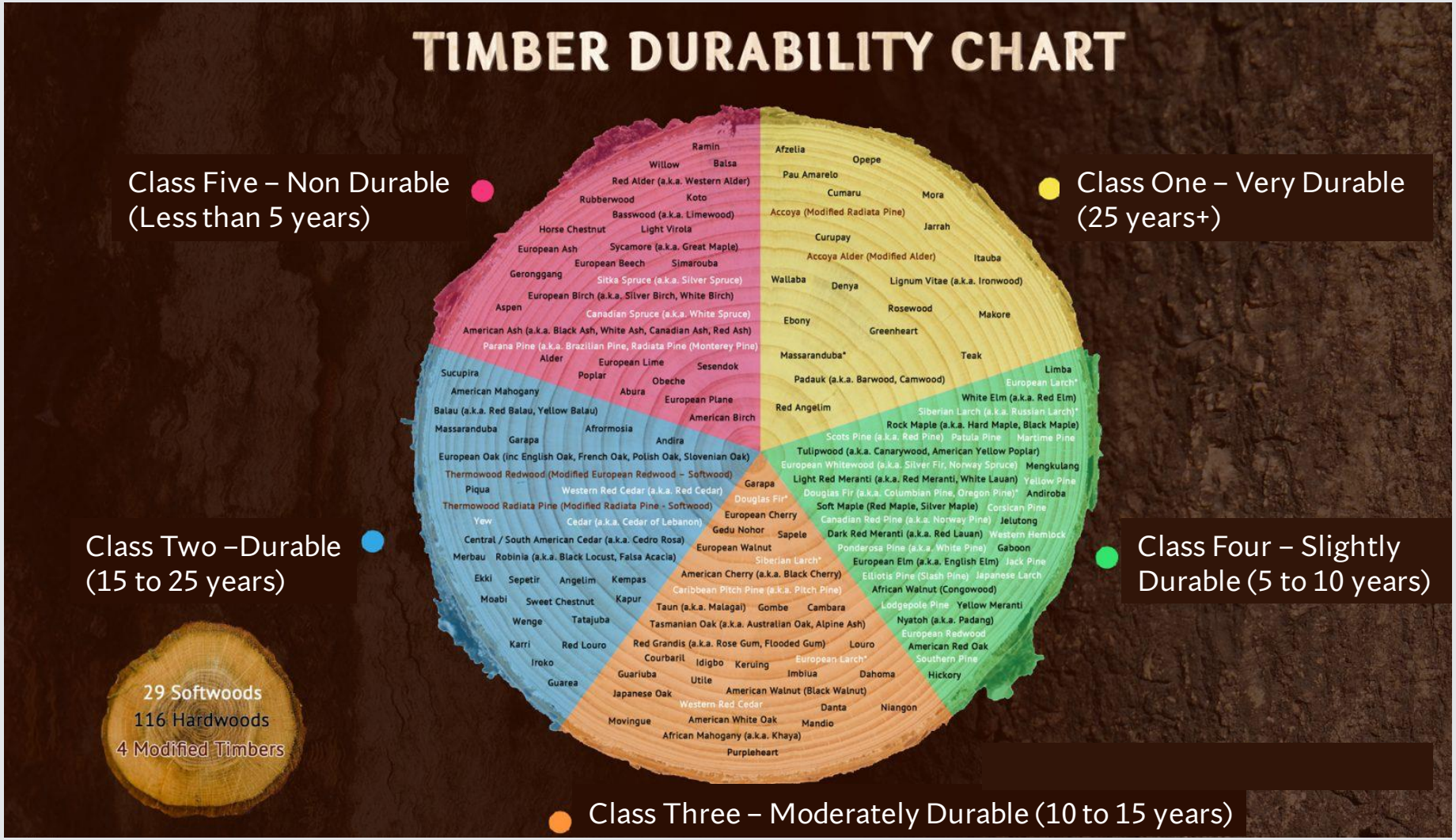


Figure 3: Timber Grades and Species [3]

2.0 SCOPE – TASK 2: Preliminary Design and Analysis

Task 2.2: Design Decision Matrix

- Create three initial, qualitative/relative designs with characteristics such as roof type and window features
- Matrix based on cost, aesthetics, and constructability to maximize competition points

Table 1: Example of Qualitative Initial Design Decisions

Aspect	Design 1	Design 2	Design 3
Roof Type	Mono-Pitched	Trusses	Ridge Beam
Window Size	2’ wide	1.5’ wide	1’ wide
Window Shape	Square	Rectangle	Triangle
Window Placement	Off-Centered and Unstacked	Off-Centered and Stacked	Centered and Stacked

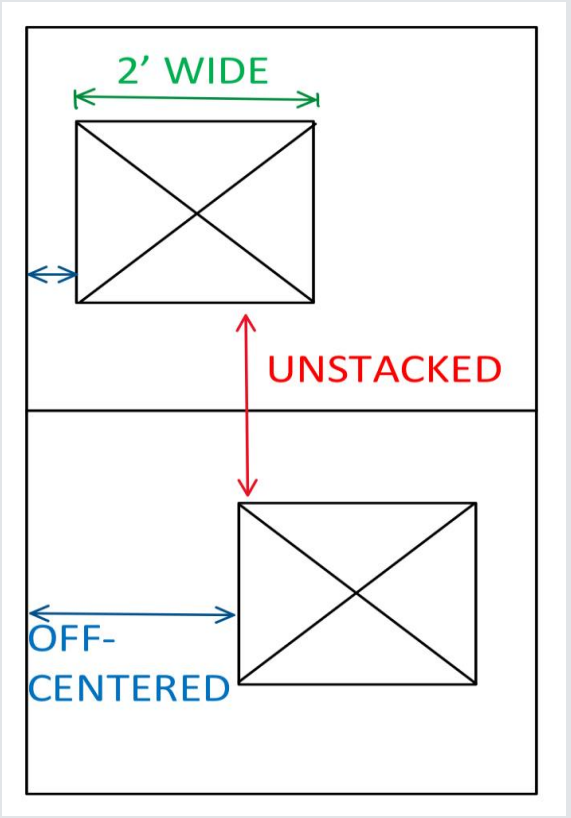


Figure 4: Example of Qualitative Window Design [4]

2.0 SCOPE – TASK 3: Final Design and Analysis

Task 3.1: Determination of Loads

- Gravity and lateral
- Using competition rules and estimated self-weight

Task 3.2: Roof Design

- Framing members
- Roof diaphragms

Task 3.3: Wall Design

- Framing members
- Shear Walls

Task 3.4: Floor Design

- Framing members
- Floor Diaphragm
- Cantilever Beam for 150 lb point load

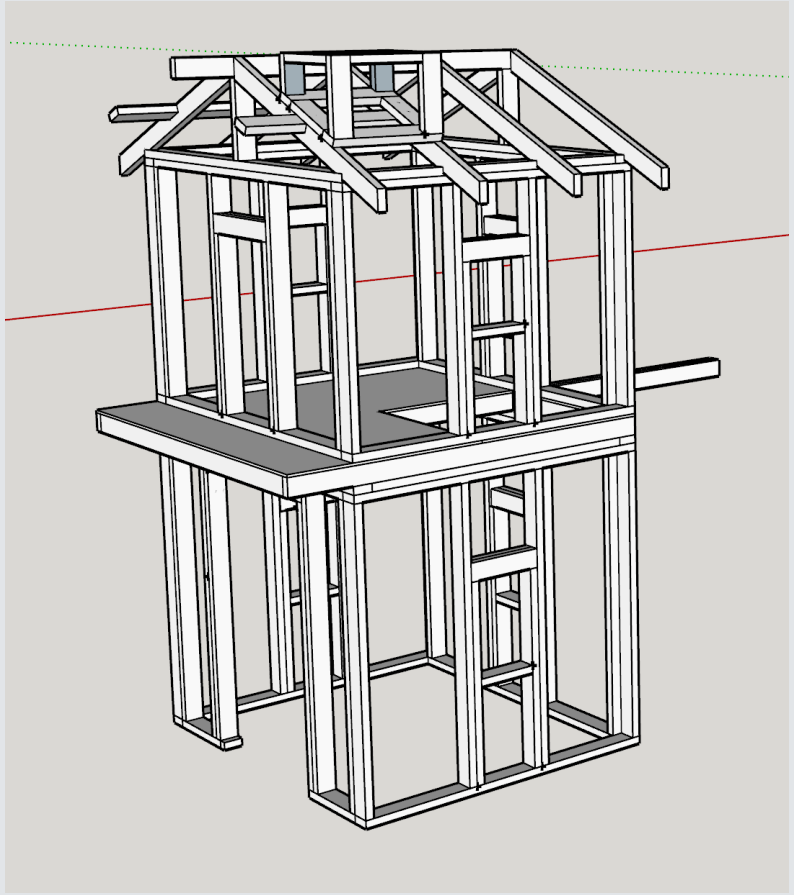


Figure 5: Model of Structure [5]

Equation 1[5]:
Allowable Stress Design

$$\frac{R_n}{\Omega} \geq R_a$$

R_n: Nominal Capacity
Ω: Safety Factor
R_a: Applied Load

2.0 SCOPE – TASK 4: Modeling

For ASCE Submittal

Task 4.1: 2D Structural Drawings

- AutoCAD per ASCE Rules

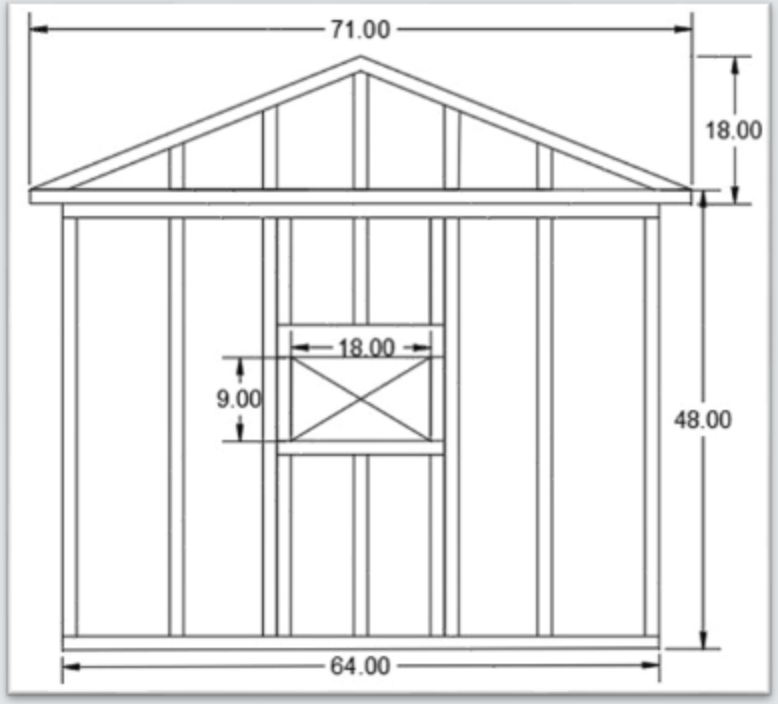


Figure 6: Example of Structural Drawing [6]

Task 4.2: 3D Building Informational Modeling (BIM)

- Revit per ASCE Rules

Figure 7: Example of BIM Modeling [7]

2.0 SCOPE – TASK 5: Construction (at NAU)

Task 5.1: Material Acquirement and Prefabrication

- Timber from HomeCo
- Hardware provided by Simpson Strong Tie
- Measure and cut all members
- Prefabricate the wall panels

Task 5.2: Construction Practice

- To prepare for 90-minute competition
- Team roles and screw placement

Figure 8: 2022 Prefabrication [1]

Figure 9: 2022 Prefabrication [1]

2.0 SCOPE – TASK 6: Competition (at USU)

Task 6.1: Trailer Preparation and Transportation

- Packing the trailer with other ISWS teams
- Material and personnel transportation to USU

Task 6.2: Competition Build Day

- 90 minutes to complete structure in 20ft x 20ft area
- Judging of structure by professionals
- Test 150 lb point load on cantilever beam

Figure 10: 2022-2023 Competition Build Day [8]

2.0 SCOPE – TASK 7: Investigate Project Impacts

- Social
- Environmental
- Economic

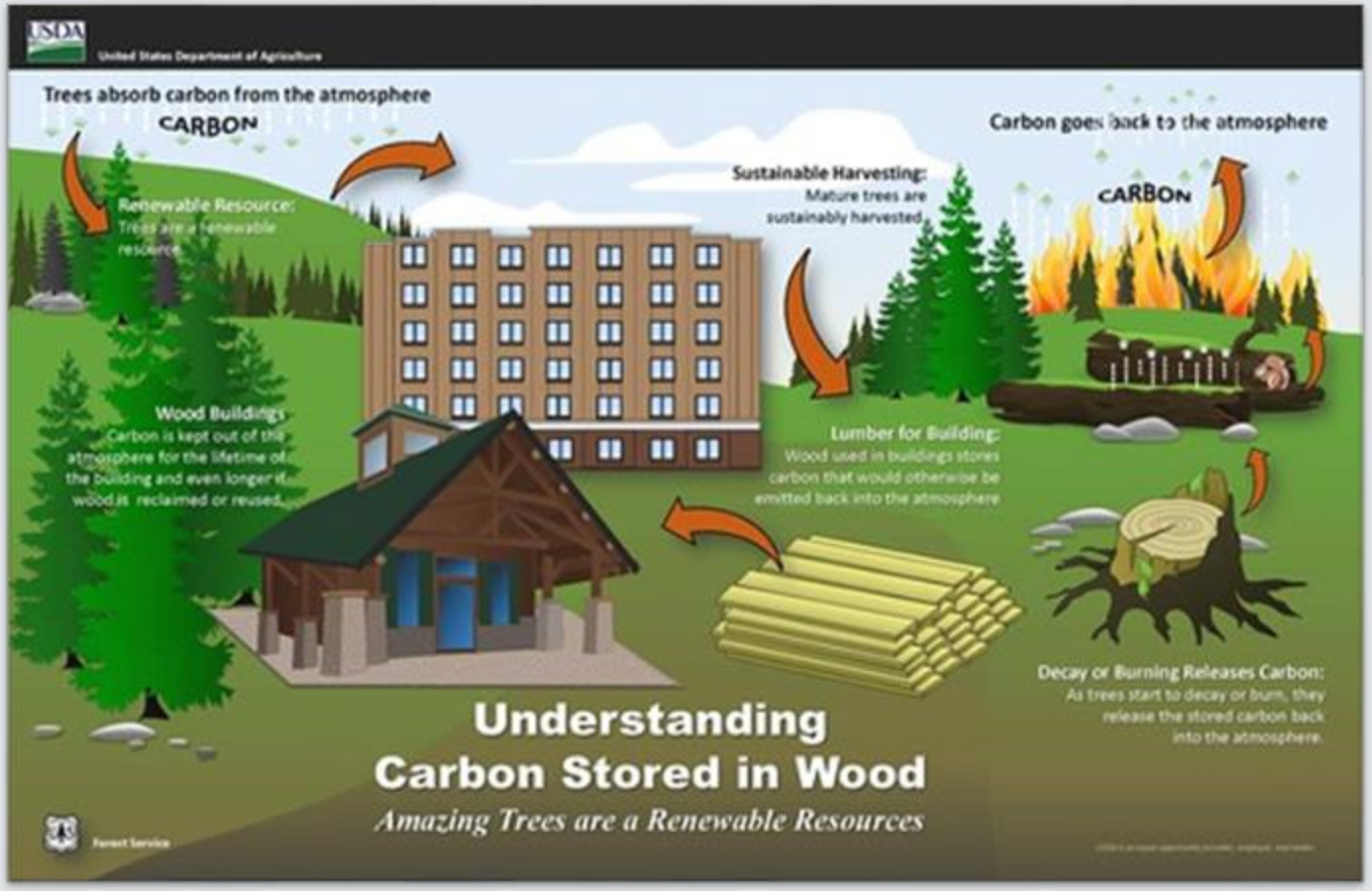


Figure 11: Carbon Footprint Cycle [9]

2.0 SCOPE – TASK 8: Project Deliverables

Task 8.1: Capstone Deliverables

- 30% Submittal (Tasks 1-3 Completed)
- 60% Submittal (Task 4 Completed)
- 90% Submittal (Tasks 5, 8.2 Completed)
- Final Report, Presentation, and Website

Figure 12: NAU TimberStrong Logo [10]

Task 8.2: Competition Deliverables

- Registration
- Project Report (Phase 1)
- 2D Drawings and 3D Modeling (Phase 2)
- Presentation (Phase 3)
- Visual Aid (Build Day)

Figure 13: ASCE Logo [11]

2.0 SCOPE – TASK 9: Project Management

Task 9.1: Resource Management

- Budget
- Staffing

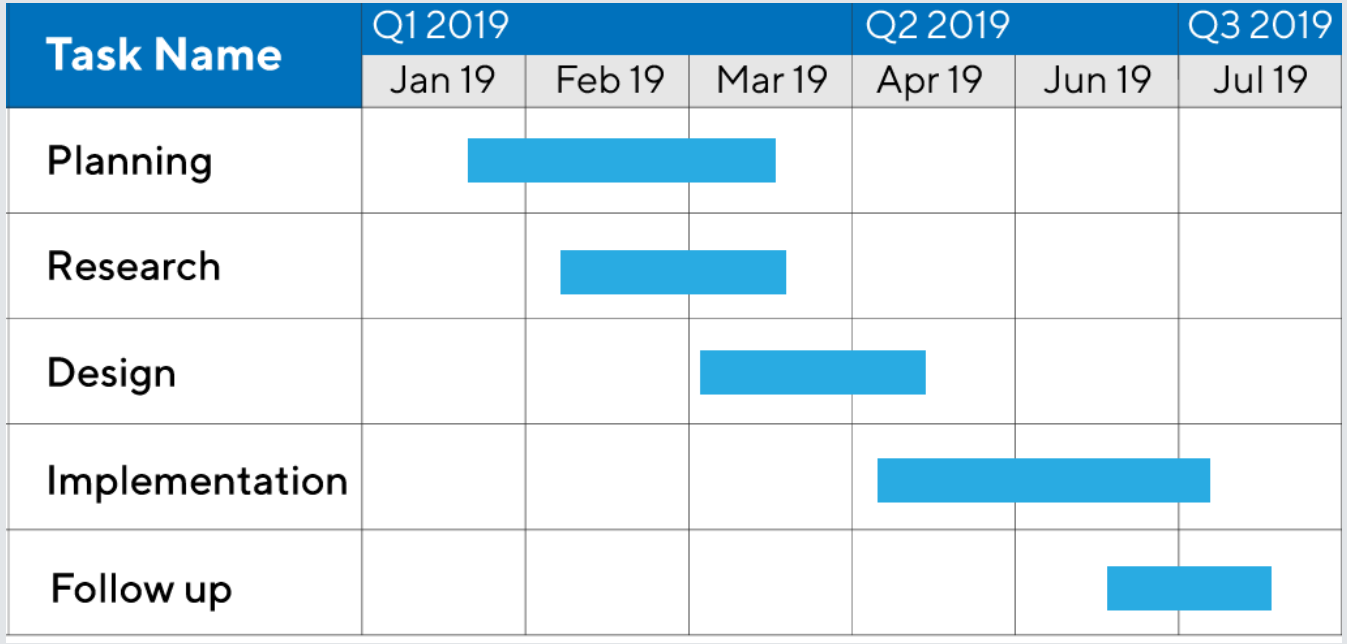
Task 9.2: Schedule Management

- Gantt Chart

Task 9.3: Meetings

- Team
- Client
- Mentee
- Technical Advisor
- Grading Instructor

Figure 14: Example of Gantt Chart [12]



2.9 SCOPE – Project Exclusions

- ASCE Student Chapter Report and Dues
- Anchor Bolt Placement

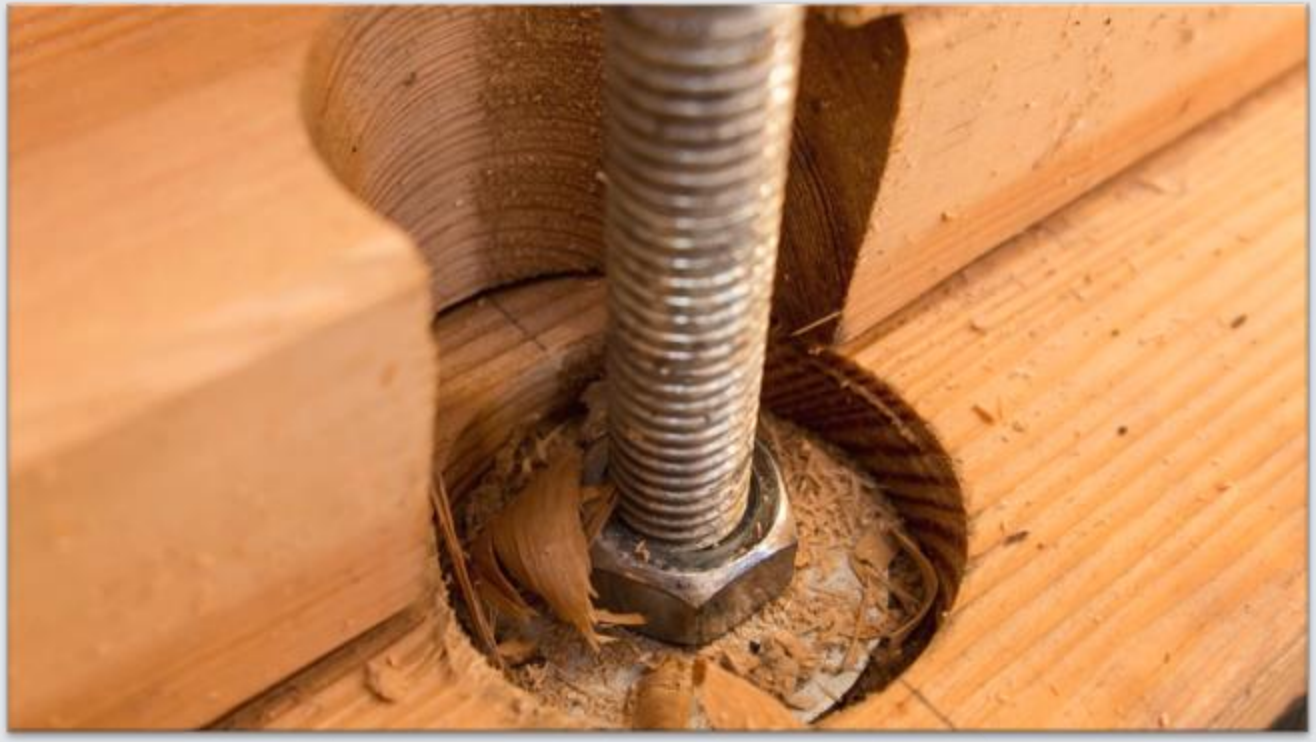
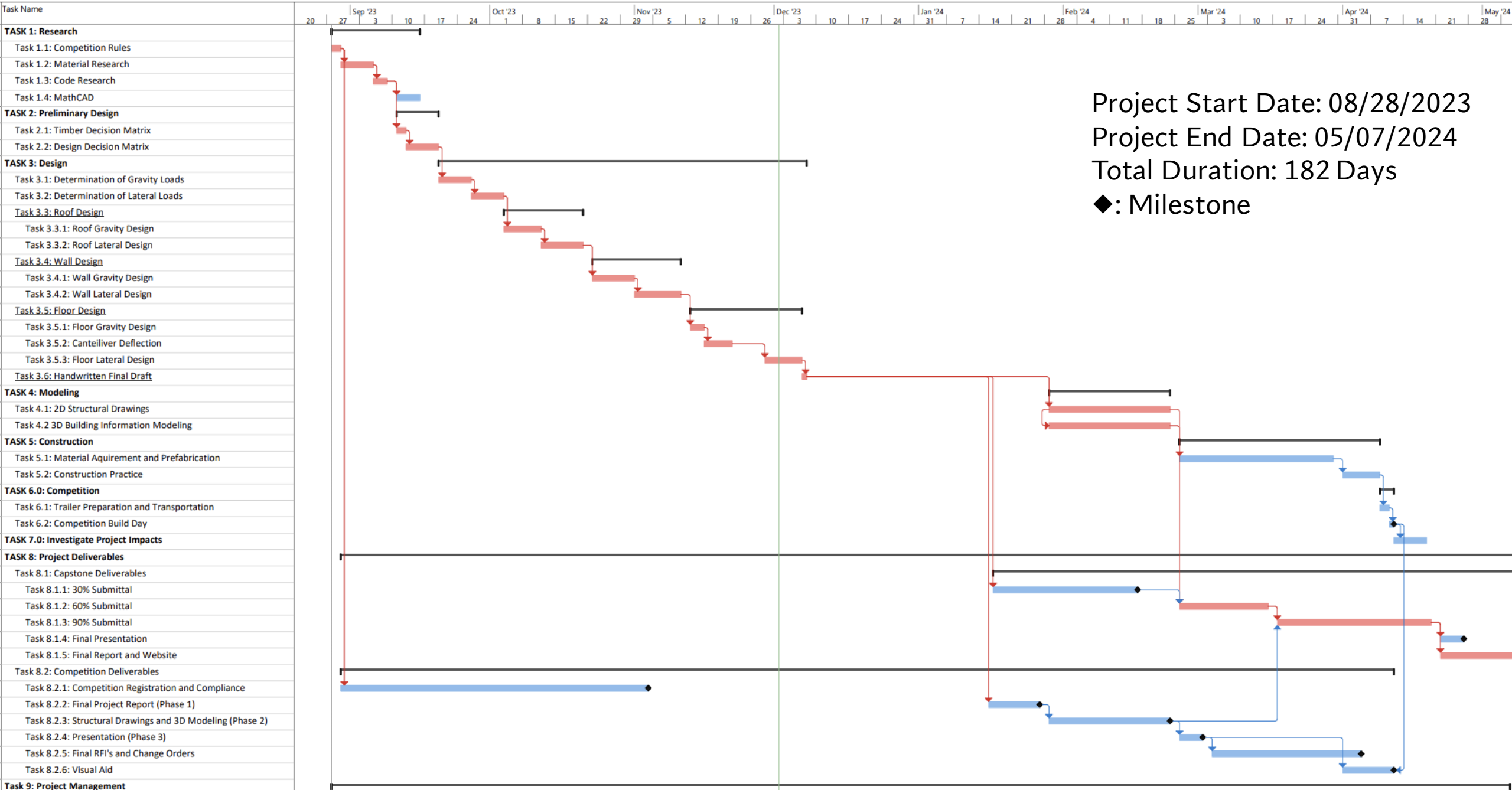


Figure 15: Anchor Bolt [13]

3.0 SCHEDULE – Gantt Chart

Figure 16: Gantt Chart



Project Start Date: 08/28/2023
Project End Date: 05/07/2024
Total Duration: 182 Days
◆: Milestone

4.0 STAFFING

Senior Engineer:
- Project management
- QA/QC

Engineer:
- Design
- Reporting/ deliverables

Intern:
- AutoCAD/Revit
- Construction
- Learn each task

Field Technician:
- Prefabrication and material acquirement
- Builds in competition

Safety Officer:
- Enforces safety regulations
- Provides construction oversight

Table 2: Staffing Matrix

Position	Senior Engineer	Engineer	Field Technician	Intern	Safety Officer	TOTAL
Task 1: Background Research	3	8	3	5	1	20
Task 2: Preliminary Design & Analysis	2	6	0	2	0	10
Task 3: Final Design & Analysis	14	54	0	22	0	90
Task 4: Modeling	2	12	0	16	0	30
Task 5: Construction	0	4	25	25	19	73
Task 6: Competition	0	0	19	9	4	32
Task 7: Investigate Project Impacts	3	0	3	0	1	7
Task 8: Project Deleiverables	18	48	3	12	0	81
Task 9: Project Management	30	53	3	25	1	112
TOTAL	72	185	56	116	26	455

5.0 COST OF ENGINEERING SERVICES

Personnel:

- Hours

Travel:

- Van Rental
- Hotel Rooms
- Per Diem

Lab Use:

- Field Station

Materials:

- Timber
- Fasteners/Hardware
- Decorations

Table 3: Cost of Services

Description	Quantity	Unit of Measure	Rate ($)	Cost ($)
Personnel				
Senior Engineer	71	Hr.	250.00	17,750
Engineer	185	Hr.	160.00	29,600
Field Technician	56	Hr.	60.00	3,360
Intern	113	Hr.	40.00	4,520
Safety Officer	26	Hr.	85.00	2,210
			Subtotal Personnel	$57,440
Travel For Competition				
Transportation	600	Miles	0.42	252
Van Rental	3	Day	71.40	214
Hotel Rooms	3	Nights (3 Rooms)	480.00	1,440
Per Diem	8	People ($60 per day for 3 days)	180.00	1,440
			Subtotal Travel	$3,346
Lab Use				
Field Station "Farm"	7	Days	100.00	700
			Subtotal Lab Use	$700
Materials				
2x4x8 Hem Fir	80	Unit	5.69	455
2x4x10 Hem Fir	2	Unit	10.67	21
OSB	15	Sheets	29.98	450
Fasteners	2	Unit	40.53	81
Connectors / Hardware	1	Unit	130.30	130
Paint	3	GAL	40.00	120
			Subtotal Materials	$1,258
			Project Total	$62,744

References

[1] J. Hays, *Construction Photos,* Flagstaff and Las Vegas, 2022.

[2] J. Hays, *MathCAD Example,* Flagstaff, 2023.

[3] "Timber durability classes," The Wild Deck Company, https://www.thewilddeckcompany.co.uk/about/timber-durability-classes/ (accessed Nov. 26, 2023).

[4] J. Hays, *Window Drawing,* Flagstaff, 2023.

[5] M. Clitso, *SketchUp Model,* Flagstaff, 2023.

[6] J. Hays, *Structure Design Sketch,* Flagstaff, 2023.

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[9] P. by W. Shoutis, "The wonders of wood buildings," USDA, https://www.usda.gov/media/blog/2016/06/03/wonders-wood-buildings [Accessed 8 October 2023).

[10] J. Hays, *NAU TimberStrong Logo,* Flagstaff, 2023.

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[13] D. Brandt, "How To Attach Wood To Concrete (Do It Right The First Time)," Building Elements, 12 March 2023. [Online]. Available: https://greenbuildingelements.com/how-to-attach-wood-to-concrete/. [Accessed 8 October 2023].

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Questions?