BYU ENGINEERING
Civil & Construction Engineering

CAPSTONE

TIMBER-STRONG DESIGN BUILD COMPETITION
PROJECT ID: CEEN_CPST_006

by

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A Capstone Project Final Report

Submitted to

Dr. Kevin Franke
Brigham Young University

Department of Civil and Construction Engineering
Brigham Young University

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Executive Summary

PROJECT TITLE: TIMBER-STRONG DESIGN BUILD COMPETITION
PROJECT ID: CEEn_CPST_006
PROJECT SPONSOR: Brigham Young University
TEAM NAME: Nebula Designs

The objective which the sponsors of the Timber-Strong Design Build Competition have set for said competition is for students to “[create] a sustainable, 2-story wood light-framed building.” The building to be built must be artistically creative, sustainable, aesthetically pleasing, and structurally sound. Basic guidelines for the design and construction of the building are specified by the competition sponsors, as are tasks to be accomplished and works to be submitted in the course of the competition. As such, this project’s course runs five months, in accordance with the schedule and guidelines established by the competition sponsors. The task of our team was to effectively convey the construction and design of this building in four formats: a written report (including structural and sustainability calculations) to be submitted in early January; structural drawings to be submitted in early February; an oral presentation with visual aid submitted in early March; and the constructed building presented at ISWS in mid-April.

These four “formats” comprise the primary deliverables to the competition organizers. However, in the course of meeting with our faculty mentor, we came to see the refining of the competition process here at BYU as a secondary objective of our Capstone project. As this is the first year that BYU has participated in the Timber-Strong competition, we sought to take note of things we learned from the process such that future competitors can do even better, ensuring a bright future for the competition at BYU. As such, we also created a summary of tips and notes for future competitors and faculty advisors, which is our fifth surprise deliverable.

The construction of a wood light-frame structure offers valuable experience with structural calculations, sustainability and safety considerations, and construction alike. While we hoped to compete well, we ultimately desired and were committed to the successful completion of each stage of development in such a way as to facilitate learning, creativity, and growth. We believe that we have achieved this, as we have learned from one another in each stage of the project and provided a valuable starting point for future Timber-Strong competitors at BYU.

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Introduction

In the course of completing this Capstone project, there were certain considerations which needed to be recognized. First, the importance of the Timber-Strong Design Build competition itself. In the competition rules document, it is stated that “while other natural resources are rapidly depleting, wood is the only building material that grows naturally, is 100% renewable, and outperforms other building materials in overall carbon footprint reduction.” Thus, the competition encourages students to design "an artistically creative building that is sustainable, aesthetically pleasing and structurally durable.” Additionally, in the interest of sustainability, after the Intermountain Southwest Symposium the project is to be disassembled and donated for repurposing.

With a clear reason for competing, and an idea of what there is to be learned from this competition, we were able to begin to address our primary design problems. We were tasked with designing a 6’x6’x12’ (max) structure, following the basic design laid out in the rules as shown in Appendix B. We also were required to create a team of 4-6 builders, two of whom must be underclassmen. As such, our first few tasks were to get intimately familiar with the rules document and recruit underclassmen to our build team. The former task was accomplished through individual reading of the document, and the second by reaching out to Dr. Kevin Franke about telling students in the Civil and Construction Engineering 101 course about the competition. We had many interested students, and settled on three who we were particularly interested in working with, ending with two underclassmen who were able to compete with us in November of 2022.

Our next step was the basic structural calculations, incorporating the layout and limitations given in the competition rules document. Structural calculations were completed by the team member who had taken the wood design course in December of 2022, and then checked by Dr. Johnn Judd in early January. These structural calculations were added to the “Report” asked for in the rules document, which also included sustainability and budget calculations and information about the team. We submitted the Report on January 16 as required by the rules.

With our report submitted, we were able to begin developing structural drawings of our building, and begin ordering materials. The structural drawings were completed in Revit by our team software specialist, and submitted to the competition organizers on February 3, 2023 per the competition rules. We worked out some budgeting questions with the department, as since this was the first year of the competition there was no precedent to work off of, and materials began rolling into the structures lab!

From here, we began a good deal of concurrent activity. Our framing expert created a framing plan, which required some modifications to our original design. These modifications were all structurally sound, as verified by the calculations expert. While the framing plans were being made, and framing itself being done by various team members, we also developed a short video presentation about our project. This was submitted to the competition organizers on March 3, 2023.

Building was done primarily on Fridays and Saturdays by the team members available from early March to mid-April. Our framing expert was present at all build days. In late March, we also put together a poster to stand beside our structure when it is built at competition. This poster will be "submitted," or viewed by the judges, on April 15, 2023. This is also the day on which the build team will construct the light-frame structure at the competition. In order to prepare for this facet of our project, the team met on April 7, 2023 to perform a practice build, thus verifying that the structure could be put up in the 90 minute time frame required by the competition.

Throughout this process, all team members were asked to make note of things which they wished had been done differently, or things we learned about the competition, such that we would have a list of ideas for future competitors. It must be acknowledged that this project was both more and less challenging than expected. On the one hand, we were pleasantly surprised by the generous timeline provided in the competition rules, which allows for approximately one month between each phase of submission. On the other, however, we found that there were elements we would have liked to begin on earlier than the timeline in the rules. That being said, ultimately we were able to accomplish all of the tasks set out by the competition organizers as well as those we decided to take on in order to ensure the future of the competition at BYU.

This competition provides a great deal of opportunity and fun to the students who participate in it. It also provides a healthy amount of challenge, and in a material which, until now, has not had a competition or club associated with it at BYU. While it is important for the competition organizers to promote interest in and knowledge of timber construction, it is also important for the American Society of Civil Engineers faculty advisor to have a strong foundation to build on as the competition moves forward. While there are things which we would change if we did the competition over again, we believe that our acknowledgement of those changes is an important part of providing that foundation—and of adjusting as we strove to meet the competition requirements.

Schedule

The following is a basic timeline as events transpired in the course of completing this project. It includes milestones related to our basic tasks, as well as notes on accomplishments and challenges.

- Dec. 15, 2022 – Jan. 2, 2023: Structural calculations are completed. The calculations are emailed to Dr. Judd for review on January 2, 2023.
- Jan. 2, 2023 – Jan. 16, 2023: Elements of first report are worked on individually and compiled. Report is submitted on January 16, 2023.
- Jan. 16, 2023 – Feb. 3, 2023: Structural drawings are worked on and reviewed. Full set of drawings is submitted on February 3, 2023.
- Jan. 27, 2023: A medical condition requiring the reorganization of the competing building team is discovered. An email informing the competition organizers and requesting a change is sent. (Affirmative reply received on Feb. 20, 2023.)
- Feb. 13, 2023: Full team is finalized and a group chat including underclassmen builders is made.
- Feb. 3, 2023 – March 3, 2023: Photos, video, and script writing for the video presentation are acquired. The full video presentation is submitted on March 3, 2023.
- Feb. 16, 2023: Materials request is sent to Simpson Strong-Tie Company, sponsors of the competition who provide connections for competing teams.
- Feb. 25, 2023: Our first build day in the structures lab. All team members are present for building on this day. We make a list of materials we will need more of, and our framing expert works on framing plans.
- Feb. 25, 2023 – April 7, 2023: Build days! As available, team members go to the structures lab to help with framing, sheathing, and assembly. During this time, decorative panels are also made for the outside of the structure.
- April 8, 2023: The build team comes together to practice the construction of the structure per the requirements set out in the rules.
- April 11, 2023 – April 15, 2023: The build team attends ISWS and competes in the build portion of the competition on April 15, 2023.

Assumptions & Limitations

The primary limitations in this project were the constraints given to us in the rules document for the competition. These limitations include certain assumptions in some cases. The primary assumptions and limitations provided to us come in the categories of calculation/design, and construction/safety.

The primary calculation/design limitations given to us were as follows:

- The structure was to be two stories tall, with the first story standing 5' tall and the second 3' tall minimum. The total height of the structure was to be a maximum 12'.
- Every wall surface was to contain a door or window opening. The door opening is required on the first story, with the door measuring in at 2'-6" wide and 4'-6" tall. Window opening areas were to be between 3.33% and 35% of the wall surface area.
- The footprint of the structure was not to exceed 6'x6', with the exception of the cantilever beam, wall sheathing, and roof eaves.
- The cantilever beam is to extend 4' beyond the building footprint, and is not to exceed 6" in depth. The beam was to be located at least 12" away from the inside faces of the walls, and be able to hold a point load of 150 lbs at its end with 0.5"-1" of deflection when loaded. The moment the beam must resist was given, and was 600 lb-ft at the wall surface.
- One 2'-6"x2'-6" access opening was to be placed on the second floor.
- Floor framing was not to exceed 6" in depth.
- We were required to use ASD calculations, and to use calculation methods as laid out in ASCE 7-22, NDS 2018, and SDPWS 2021. The ASD calculation method assumes a constant factor of safety for all designs, regardless of load type.
- We were given gravity design live loads for the floor and roof, and asked to calculate the dead loads based on our design choices. The live load given for the roof was 20 psf, and for the floor was 50 psf. For the lateral design, we were also given seismic lateral and transverse loads for the roof and floor, and a wind uplift load to resist with the roof connections and framing. The seismic roof load was 275 plf, seismic floor was 225 plf, and the wind uplift load was 30 psf.
- We were not allowed to use dead load to resist uplift.
- We were required to specify hold-downs and anchors for our shear walls, and calculations for these elements were performed assuming that the structure would be anchored to a foundation when constructed. However, in practice, the

structure was not allowed to be anchored to any foundation during competition. We were required to use ½” diameter anchor bolts.

- We were required to use Simpson Strong-Tie (SST) products for connections and fasteners, as SST is a primary sponsor of this competition.
- All framing materials were to be at a minimum of nominal 2 x sawn lumber (Douglas Fir (DF), Southern Pine (SP), Douglas Fir-Larch (DF-L), Hem-Fir (HF) or Spruce-Pine-Fir (SPF)) or engineered wood products. Wood structural panels (plywood or oriented strand board (OSB)) were permitted to be used for the diaphragm and shear walls (structural insulated panels (SIPS) were not permitted).

The primary construction limitations provided to us were as follows:

- We were required/allowed to prefabricate all wall and flooring panels except for the roof prior to competition. This is a policy in place to ensure the safety of competitors, such that they do not have to lift a heavy roofing panel into place from ladders during competition.
- While pressurized nail guns and rotating saws were permitted for prefabrication, no compressed air, powder actuation, or rotating blades were allowed on site during construction. Battery-powered drills, drivers, etc. were allowed, however.
- It was assumed that members of the build team would have completed basic safety training to work with battery-operated tools. It was required that all members of the team complete a basic ladder safety training prior to submitting the first phase of documents.

Working within these assumptions and limitations provided valuable problem-solving experience, and allowed us to learn more about working within constraints as is often the case in the real world of construction.

Design, Analysis & Results

The design, analysis, and results of our project are best summarized by walking through the various phases we were required to complete in order to participate in this competition. First of all, we were to submit a report including our structural, sustainability, and budget calculations. This comprises the preliminary, numbers-based design of our structure. This phase was completed using Microsoft Excel for structural and budget calculations, and WoodWorks for sustainability calculations. Examples of these calculations are provided in Figures 1-3. Full calculations are provided in the report we submitted for competition in the Appendix.

Cantilever Beam Info:			
PL	=	150	lbs
M	=	600	lb-ft @ wall
L	=	4	ft
Lateral support only at end			
Try:			
2x6 DF-L No. 2			
l(u)	=	4	ft
d	=	5.5	in
b	=	1.5	in
Emin	=	580000	psi
Sx	=	7.56	in^3
Fb	=	0.9	ksi
c	=	0.95	
Find:			
Is the design adequate?			
Calculations:			
l(u)/d	=	(4*12)/5.5	
	=	8.727	>7
Thus:			
l(e)	=	1.37(l(u))+3d	
	=	1.37(4*12)+3(5.5)	
	=	82.260	in
	=	6.855	ft
R(B)	=	√l(e)*d/b^2	
	=	√115.14*5.5/1.5^2	
	=	14.180	
F(bE)	=	1.2(Emin')/R(B)^2	
Emin'	=	Emin(C(M)C(t)C(i)C(T))	
	=	580*1	
	=	580.000	ksi
F(bE)	=	(1.2(160000))/(16.78^2)	
	=	3.461	ksi
Fb*	=	Fb(C(D)C(M)C(t)C(fu)C(i)C(T))	
	=	0.99*1.17*1.3	
	=	1.369	ksi

α	=	F(bE)/Fb*	
	=	3.46/1.053	
	=	2.529	
C(L)	=	(1+α)/2c - √((1+α)/2c)^2	
		- α/c)	
	=	(1+2.5)/1.9 - √((1+2.5)/1.9)^2	
		- 2.5/0.95)	
	=	0.970	
Fb'	=	Fb*(C(L))	
	=	1.053*0.98	
	=	1.328	ksi
M(all)	=	Fb'(Sx)	
	=	1.03*7.56	
	=	10.037	kip-in
	=	0.836	kip-ft
OK?	=	TRUE	
Deflection:			
Δ	=	PL^3/3EI	
	=	150(4^3)/(3*580000*20.8)	
	=	0.458	in
Conclusion:			
The beam will likely deflect more in practice, bringing			
it to 0.5". Additionally, a smaller beam is unable to			
support the applied load with the available flexural			
strength. Thus, use (1) 2x6 beam.			

Figure 1 Example of structural calculations as completed in Excel.

Material	Number Required	Number Purchased	Cost per Unit	Cost of Material	Notes
7' DF-L No. 2 2x6	16	24	$ 9.72	$ 233.28	
5' DF-L No. 2 2x6	16	24	$ 12.44	$ 149.28	*cut 10' in 2
10' DF-L No. 2 2x6	1	2	$ 12.44	$ 24.88	
6' DF-L No. 2 2x6	6	9	$ 9.72	$ 43.74	*cut 12' in 2
6' DF-L No. 2 2x8	12	18	$ 14.96	$ 134.64	*cut 12' in 2
subfloor adhesive	2	3	$ 2.97	$ 8.91	
5/16" OSB shtg	3	5	$ 12.00	$ 60.00	72 ft2 req
*7/16" OSB Structural I shtg	4	6	$ 12.00	$ 72.00	96 ft2 req
6d common nails	192 nails	2	$ 7.27	$ 14.54	
8d common nails	192 nails	3	$ 7.27	$ 21.81	
STHD14 hold downs	8	9	$ 21.35	$ 192.15	
LSTA18 tie downs	8	9	$ 1.42	$ 12.78	
PAB4-12 anchor bolts	48	52	$ 18.98	$ 493.48	
**H8 hurricane ties	6	9	$ 0.78	$ 7.02	
**0.148 x 1 1/2 fasteners	60	1	$ 4.88	$ 4.88	
16d common nails		1	$ 39.98	$ 39.98	

Figure 2 Example of budget calculations as completed in Excel.

Figure 3 Example of sustainability calculations as completed in WoodWorks.

These initial analyses concluded that our structure, with materials multiplied one hundredfold to simulate an actual building, was likely to store 50 metric tons of CO2 in the wood. The structure had a potential carbon benefit of 157 metric tons of CO2. Our budget was estimated to be $1,513.37. Our design relied on 2x8 perimeter framing members for the roof and floors, with 2x6 internal framing members in an unblocked diaphragm with 7/16” OSB sheathing. The nailing pattern was 8d nails at 6” on-center. Our shear walls were 2’ wide, and also used 7/16” OSB sheathing with 8d nails at 6” on-center. We used STHD14 hold downs and LSTA18 ties for our shear walls, and PAB4-12 anchor bolts at 6” on-center for the segmented shear walls, as well. We used 2x6 wall framing members, a 2x6 cantilever beam, and H8 ties for the roof anchorage. Our factor of safety for the diaphragm was 1.77, while for the shear walls it was 2.19. We used a flat roof approach in our design. This concluded the analysis required in our project.

It was also at this point that we created our artistic design and vision for the project. BYU has ranked #1 on the Princeton Review’s “Stone Cold Sober” and/or “Cancel the Keg” category for 24 years running. The university often celebrates the achievement with specially labeled bottles of the famous BYU Creamery chocolate milk. BYU is also well-known for a love of nerd culture, including such things as Dungeons and Dragons and Lord of the Rings. Given that our structure was required to feature a cantilever beam, the likes of which a tavern sign might hang from in days of old, we thought a fun twist on our design would be to construct a mini “chocolate milk tavern,” with inspiration for the name taken from The Lord of the Rings books.

The next phase of our project was to create structural drawings. This was accomplished in Revit. The full drawings are included in the Appendix, and were submitted to the organizers of the event as Phase 2 of our documentation. Additionally, a framing plan was created by our framing expert after the fact. Examples of both our Revit drawings and framing plans are included in Figures 4 and 5.

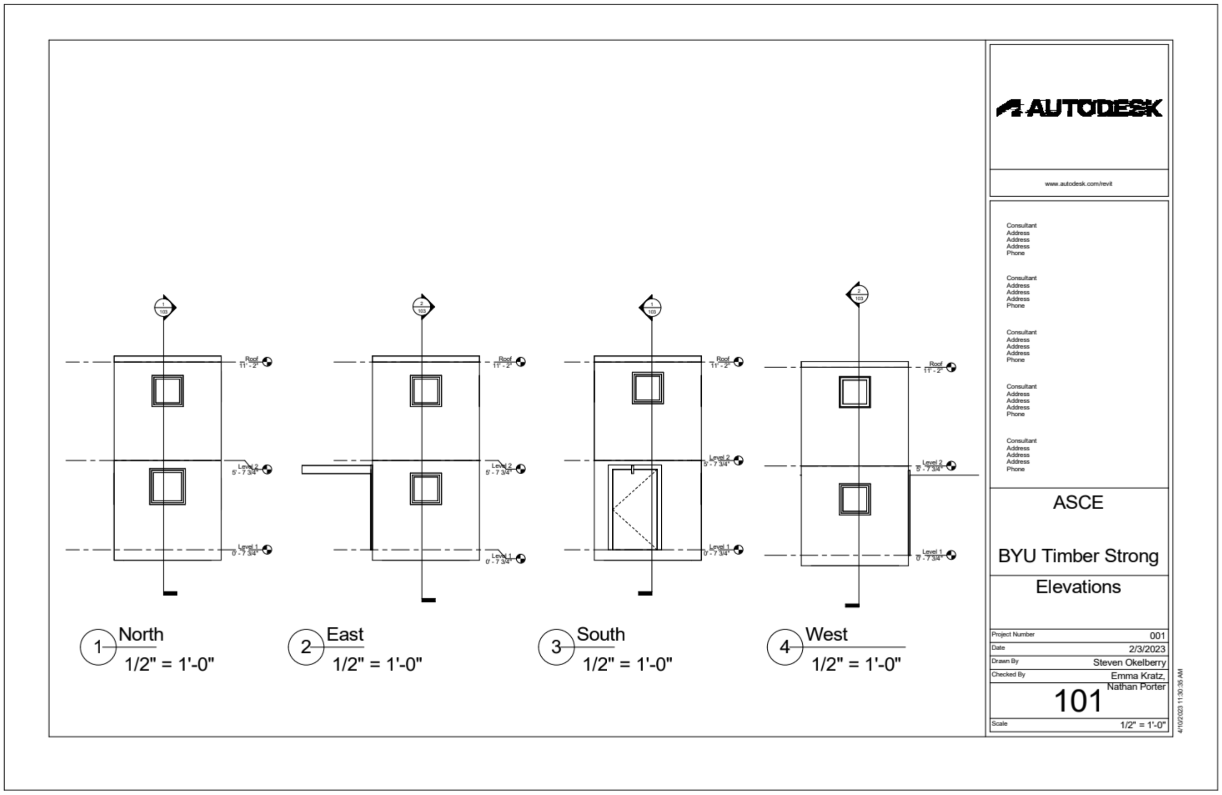

Figure 4 Example of Revit drawings generated for our structure.

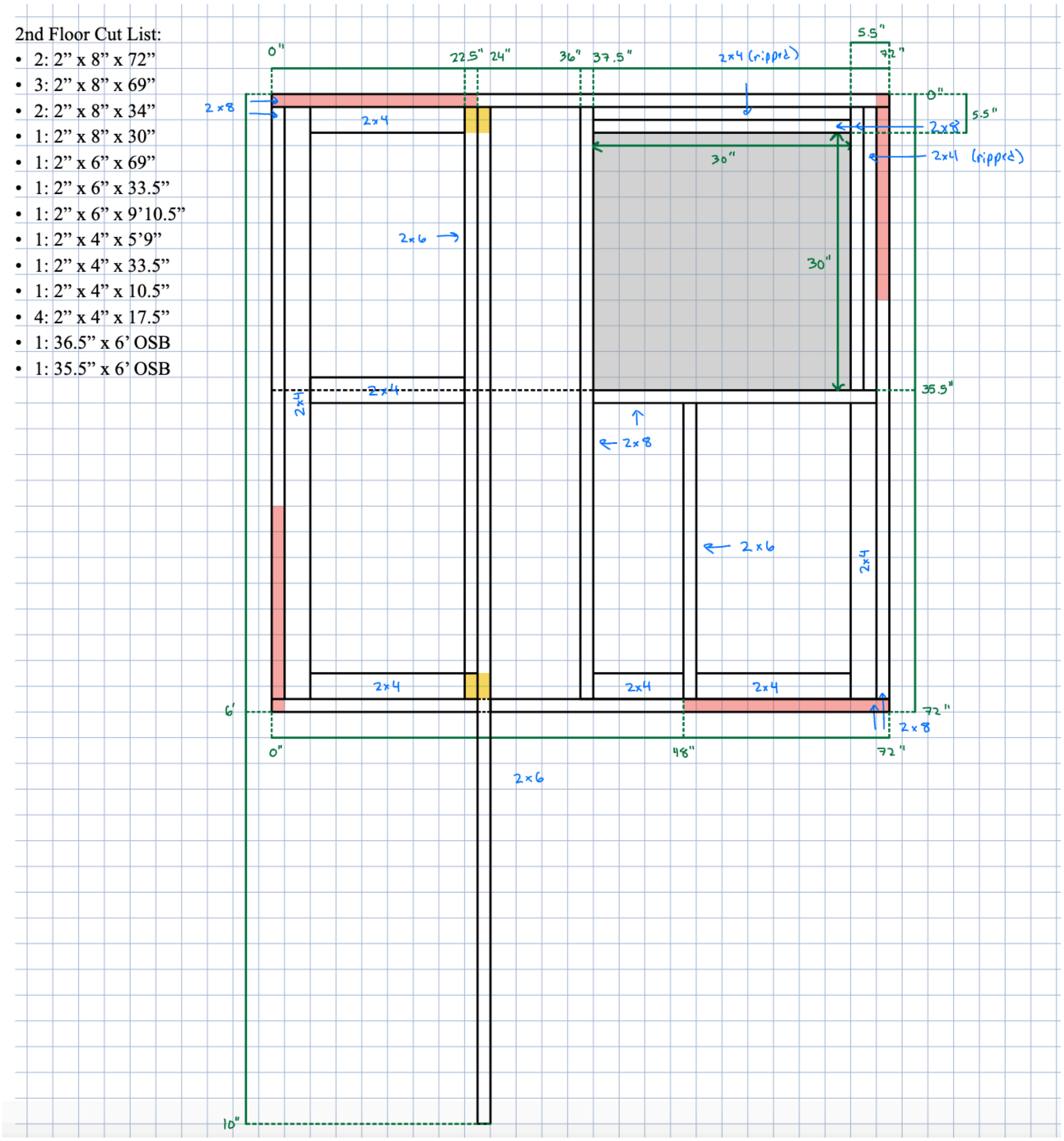

Figure 5 Example of framing plans created for construction of our project.

With our materials selected, and our plans laid out, we were able to begin building! As we built, we also created a video presentation which can be found at https://www.youtube.com/watch?v=NuOYNoEturA. This video was Phase 3 of our documentation. We also made a visual aid to be placed alongside the construction site, which is included in the Appendix. But the real meat of this part of our project was construction itself, which included collaborative work on cutting, framing, and measuring. We spent the most time by far on this aspect of our project. Some photos of our progress are included in Figures 6-10. The final result, (minus the roof, which was simply a flat one sitting on top of what is seen in this picture), is shown in Figure 11.

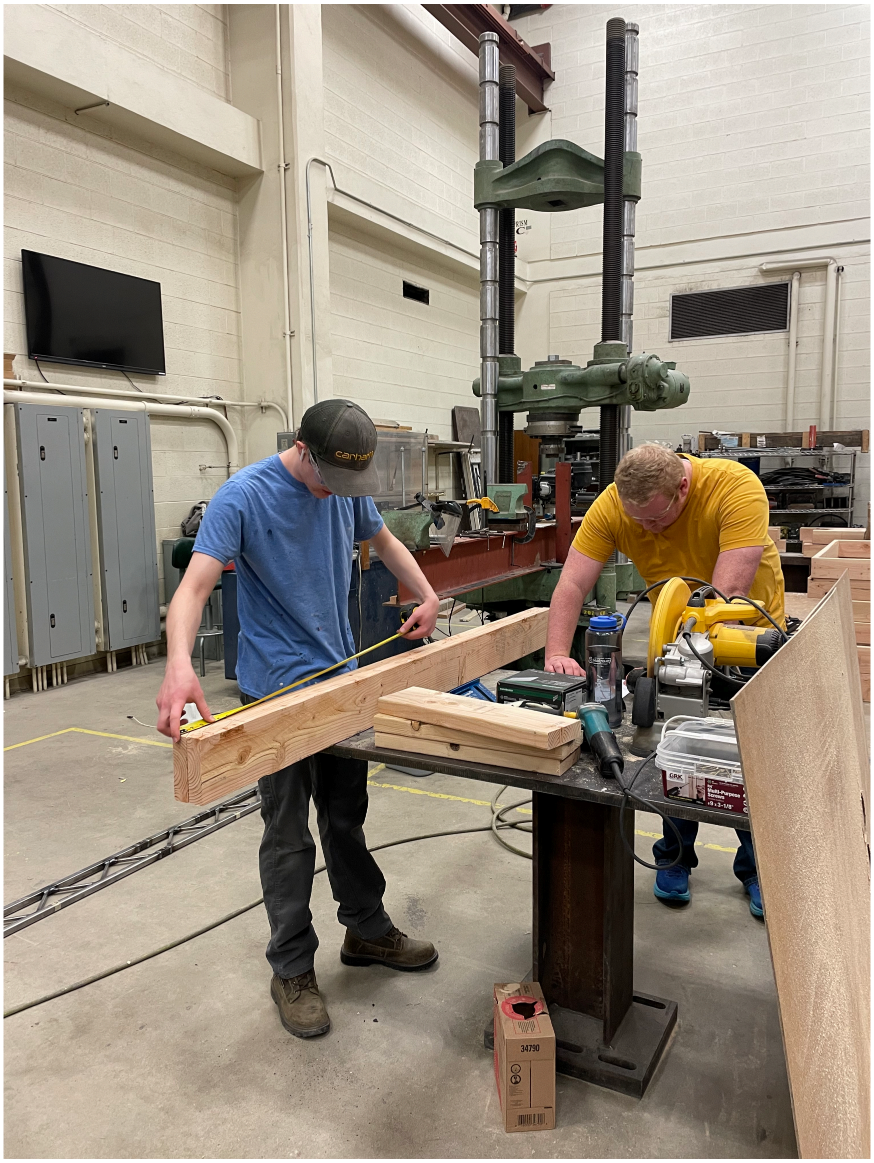

Figure 6 Team members measuring lumber in preparation to cut it for framing.

Figure 7 An image of several floors and walls, all framed and ready for sheathing!

Figure 8 Our framing expert prepares to sheath a wall.

Figure 9 Decorative cardboard panels were attached to the sheathed walls.

Figure 10 The build team works on erecting the second story of the structure.

Figure 11 The final product—our chocolate milk tavern, The Crouching Cougar!

Related Issues

This project has impacts and implications for public health, safety, global factors, environmental factors, and economic factors. The realms of public health, global factors, and environmental factors have a good deal of overlap. Wood, as mentioned earlier, is a building material that grows naturally, is 100% renewable, and outperforms other building materials in overall carbon footprint reduction. The carbon footprint reduction implies benefits for public health, as carbon tends to have negative impacts on the lungs and contributes heavily to pollution, which, in general, negatively impacts residents. As use of wood in construction increases, it can be hoped that the carbon footprint of building will be reduced and public health steadily improved. Additionally, pollution and reducing carbon footprint is a worldwide effort and issue. Thus, the use of wood in construction has potential benefit for the world around. Particularly, as various countries engage more consistently in wood construction, other countries may take note and do so, ultimately reducing the worldwide carbon footprint. However, it is also of note that lumber must be sourced sustainably, or the environmental benefits of its use in construction may be outweighed by a general loss of green spaces. This is a global issue which has been discussed for many years, and is still in talks at present around the world. Finally, as can be surmised from the foregoing discussion, wood construction is beneficial to the environment. It is, when done sustainably, easier on the environment to produce than steel and construction, renewable, and has a lower carbon footprint when used as a building material than alternative methods. Thus, this project has potential environmental benefits and implications.

Economically, the use of wood, (especially reclaimed wood), can prove a better option economically in smaller-scale construction projects such as homebuilding. However, due to its slightly weaker and less predictable behavior, wood construction sometimes results in costly engineering experiments and designs. While not necessarily an inherent negative, this is a factor that builders must consider when deciding upon a building material. Additionally, in the current economic climate, the price of building materials is fluctuating a decent amount. This means that whether or not timber construction is more economically viable than other options is difficult to say at any point in time. Additionally, the availability of timber for construction changes from place to place, making concrete and masonry construction much more economically feasible in some areas of the world. It is, thus, difficult to make net judgements on the economic factors at play in wood construction, but there is certainly *something* to be said about its impact depending on the location and type of project being constructed.

The relation of this project to safety is more personal. All of us, in the process of construction, had realizations about the methods we were using to go about our construction. Oftentimes, we realized that there were safer ways to do things, and learned why safety regulations are in place. Luckily, we didn't have any huge near-misses, but we were instructed as to proper use of various tools, proper lifting, and proper ladder use. We also ended up with several team members who were dealing with health issues in the course of the project, and keeping those people safe informed many of our construction decisions. By encouraging students to get hands-on experience in construction, this project brought home the importance of safe practice in construction process and design.

Lessons Learned

Over the course of this project, we, first and foremost, learned a lot about working together. We became better at communicating with each other, and sharing ideas without being too nervous about the others' responses. We also learned a lot about the competition itself, but the bulk of what we have to say about that aspect of the project can be found in the "Recommendations" section of this report. Finally, we learned how to overcome unexpected happenings on the team and in the project.

One of the best things about this group is our honesty with each other. We all have different strengths, which means that we are able to bring different perspectives to issues that arise. As such, when, say, we realized that we needed to have a non-prefab roof plan after having fabricated a roof, we were able to communicate quickly and make a plan to fix things. It also meant that when one of our team members encountered a health issue which prevented their participation in the construction portion of the project, we were able to adjust quickly and without undue embarrassment or drama. That free communication really made the project much easier to accomplish!

However, there were times when we were stressed by timelines and availability. At these points in time, communication again became a critical issue. We, each of us, were able to overcome our instinctual stress responses to more effectively communicate, and often supported each other directly as that overcoming was happening.

In summary, the issues we encountered in our project were primarily timeline- and availability-based,and were overcome by developing our ability to communicate effectively with one another. Over the course of just two semesters, we have learned what works best with the other members of our team, and honed our teamworking capabilities.

Conclusions

The first conclusion we have come to about this competition and this project is that a thorough and consistent reading of the rules is necessary. There were issues we encountered that could have been avoided had we all more thoroughly understood the competition rules, and made their review a regular part of our meetings. As such, another conclusion we have come to is that this project could work much better as a Capstone project in the future. Initially, we felt that we weren't putting in the hours required to justify our project as a Capstone endeavor—however, as we moved into crunch time and reflected more thoroughly, we believe that greater consistency and a quicker timeline would easily generate the hours required for this project. We also believe that incorporating more thorough team review would help generate not only more work for Capstone team members, but a better final project. Finally, we feel that if this project were organized as or associated with a club, then there would be more potential for Capstone team members to gain leadership experience and to put time into the project more consistently. These general recommendations and feelings are expanded upon in the "Recommendations" section.

On a more concrete note, we have concluded that wood construction has great potential for the future. There is a flexibility to wood design that we hadn't known about before, which can enable the creation of really interesting structures. We also found the calculations and design process enlightening, as we all now have a bit more of an idea as to how to design wood structures. We also feel that this competition has enabled those of us who will likely spend more time behind desks than in the field to get a feel for what contractors and builders encounter. Hopefully, this will enable us to be more sympathetic, knowledgeable, and helpful consultants in the future—which hope and belief leads to another conclusion: that this competition is a worthwhile and useful endeavor. We are grateful to have been able to participate in it, and look forward to applying the lessons learned to our future careers.

Recommendations

These recommendations are directed to the future organizers and participants in the Timber Strong Design-Build competition at BYU. They are the result of our long-term notes on what we would have liked to do differently in the course of this project. We are excited to see the future of the competition at BYU, and anticipate that it will only get better with time!

- TIMELINE: It is our recommendation that calculations are begun in late November, and that they are reviewed by all members of the team in order to verify accordance with competition rules prior to submission in January. Thus, it is also recommended that all members of the team read the complete rules document and make note of the important constraints in October and November. The rules document tends to spread requirements and expectations around a bit, and so engaging every team member in the rules review process should help ensure that fewer things are missed in that document. Calculations should be reviewed by the framing expert on the team, who should consult with whoever creates the budget to ensure that all framing materials will be accounted for therein. As soon as calculations are completed, the framing and Revit experts should work together to generate the Revit and framing plans, which, in the future, should be completed in Revit and submitted as one document in February. At this point, the team should be able to order materials, and building should be done a bit at a time from February to April. This will enable a more relaxed building schedule, more team bonding, and, hopefully, one-to-two full run-throughs of the construction competition.
- TEAM COMPOSITION: It is recommended that every Timber Strong Design-Build competition team going forward include people who are able to fulfill the following roles:
    - One calculations and design expert, who has taken the timber design course and has a working relationship with the timber design professor.
    - One Revit expert, who has experience in the program and can help generate professional-looking and thorough plans.
    - One framing expert, who has experience framing and knows what tools, layouts, and materials are standard.
    - One primary aesthetics director, who will refine the theme selected by the team and take point in the “architectural” design. They will need to work closely with the calculations, Revit, and framing experts in this role.

- 4-6 builders, who will be on the competition construction team and can fulfill other roles, as well. It is our recommendation that the full amount of builders be recruited if possible. Additionally, check the rules for the number of underclassmen required.

Appendix A: Resumes

Steven Okelberry

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Profile

Hardworking and fast-learning team member. Works well with others while also succeeding in personal projects. Seeking career opportunities that will apply current skills and knowledge and provide chances to expand and add to them.

Experience

SURVEY/CAD TECHNICIAN | WW CLYDE & CO | FEBRUARY 2020 – PRESENT

Managed and streamlined the processing of BIM data and plans for collaboration and construction workflows for a billion-dollar data center

Managed and performed field staking and as-builts for large civil projects

Performed take-offs and assist in estimating for bids of heavy civil construction projects

LAB TECHNICIAN | GENEVA ROCK PRODUCTS | MAY 2019 – SEPTEMBER 2019

Assisted in asphalt and aggregate materials quality control

Performed standard tests such as sieve analysis and density tests.

SERVICE VOLUNTEER/LEADER| CHRUCH OF JESUS CHRIST | JULY 2015 – AUGUST 2017

Created training programs for ecclesiastical volunteers to increase service outreach

Led and performed service projects ranging from disaster clean up to food drives

Education

BACHELOR OF SCIENCE IN CIVIL ENGINEERING | APRIL 2023 | BRIGHAM YOUNG UNIVERSITY, PROVO, UTAH

Survey/GIS, Fluid Mechanics and Hydraulics, Project Management, Structural Analysis, Soils Mechanics

Participated in ASCE's Concrete Canoe Timber-Strong Design Build competitions

Skills & Software Knowledge

AutoCAD/Civil3D

Trimble Business Center

Material Testing

Microsoft Office Suite

VBA

ArcGIS

Emma Kratz-Bailey

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Profile

Mandarin-speaking aspirant architect and structural engineer, with a penchant for all things vintage.

Experience

ENGINEERING INTERN | DUNN ASSOCIATES, INC. | MAY 2022-AUGUST 2022

Developed drawings in collaboration with fellow interns and professional engineers for submission to clients

Cultivated a working knowledge of the construction and structural engineering industries in order to integrate into the industry

Performed basic structural calculations using various softwares for use in developing structural drawings

RESEARCH ASSISTANT | BRIGHAM YOUNG UNIVERSITY | MAY 2021 – OCTOBER 2022

Developed design for self-centering beam system capable of self-centering buildings up to 4% story drift

Created and contributed to papers presented at two conferences

Developed 51-page thesis exploring and explaining research

SERVICE VOLUNTEER/LEADER| CHRUCH OF JESUS CHRIST | JULY 2015 – AUGUST 2017

Created training programs for ecclesiastical volunteers to increase service outreach

Led and performed service projects ranging from disaster clean up to food drives

Education

BACHELOR OF SCIENCE IN CIVIL ENGINEERING | APRIL 2023 | BRIGHAM YOUNG UNIVERSITY, PROVO, UTAH

Minor in Mandarin Chinese

President of the BYU Chinese Club from August 2019 to August 2022

SEAU Student Ambassador

Robert K. Thomas Honors Scholarship Recipient

Skills & Software Knowledge

AutoCAD/Civil3D

RAM Structural System

RAM Elements

RAM Connect

Enercalc

Microsoft Excel

Nathan D Porter

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www.linkedin.com/in/nathan-porter-2123a924b/

EDUCATION

Brigham Young University, Ira A. Fulton College of Engineering Apr 2023
Bachelor of Civil Engineering, STEM Field, Emphasis in Geotechnical Provo, Utah

- Major GPA 3.57

SKILLS

- **Proficient:** Communicating via digital and in-person means, Wood Framing and Construction, Painting
- **Moderate:** CAD, ArcGIS, VBA, Structural Analysis, Material Science
- **Familiar:** Python

RELEVANT EXPERIENCE

Structural Analysis Python Code Project Aug 2021 – Dec 2021
Class Member Provo, Utah

- Studied Python Coding and Boolean Logic through online courses to learn basics of Python
- Experimented with multiple methods of structural analysis to understand best method for application in Python
- Consulted with other students and professor and wrote Python code to perform Method of Joints on a Truss

COVID-19 Effects on Aviation Research Team Aug 2021 – Dec 2021
Team Leader Provo, Utah

- Organized research subjects and assigned topics to individual team members to ensure everyone had a solid understanding of specific topics
- Coordinated with team members through text, email, and Zoom to keep everyone accountable and up to date
- Created a presentation in MC PowerPoint and gave presentation with team on research and needed action to inform others of important trends in the Aviation Industry

Rocky Mountain ASCE 2021 Student Conference Jan 2021 – Apr 2021
ASCE BYU Student Chapter Member Provo, Utah

- Designed prototype greenhouses using AutoCAD to perform cost-benefit analysis with team and select best version for customer
- Researched materials to select low cost, recycled materials that would be most heat efficient for maintaining constant temperature
- Constructed and tested proof-of-concept using proposed design and came in first place in the Design competition

Appendix B: Basic Layout from Rules

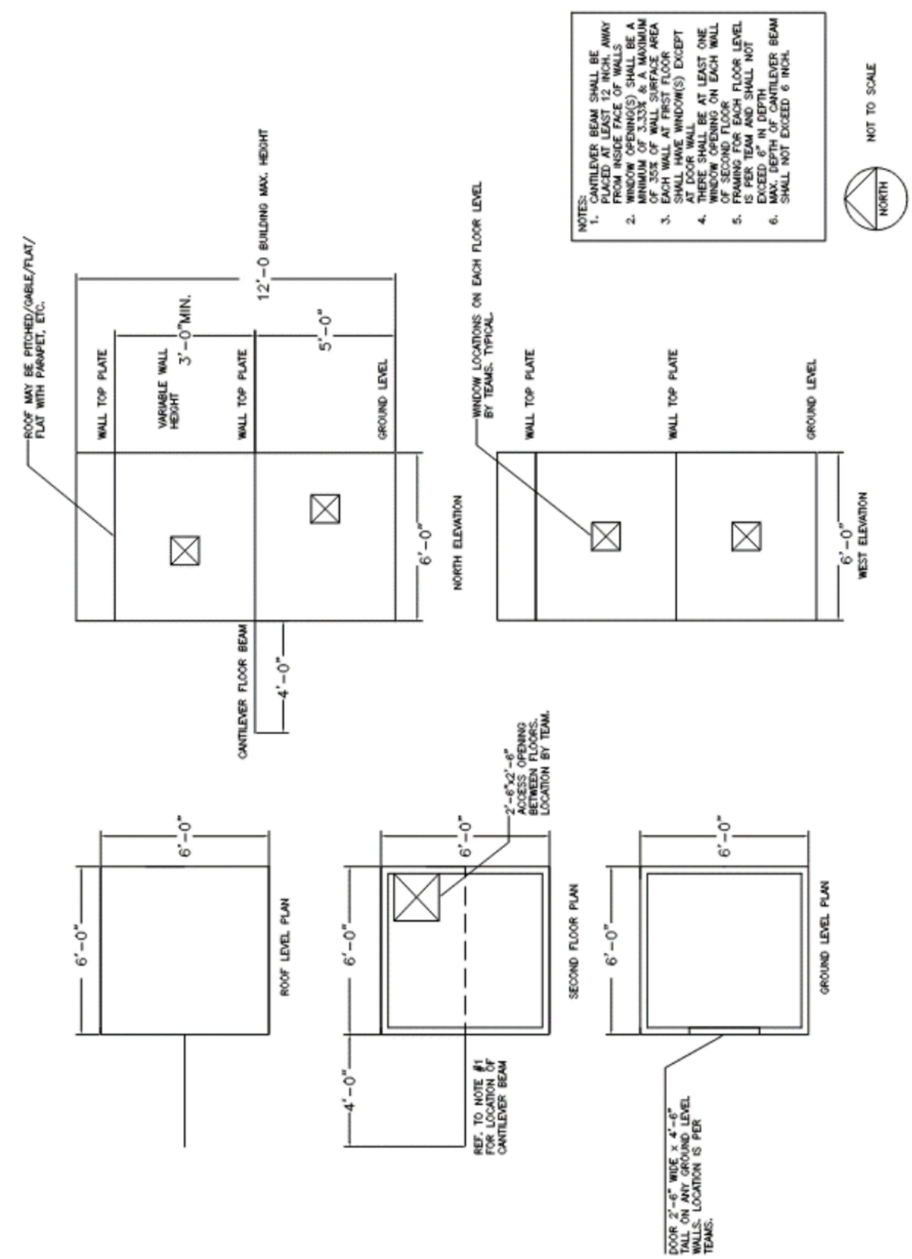

Figure 1.

Appendix C: Phase 1 Report

BYU ASCE Student Chapter

Timber Strong Design-Build Competition

Phase 1 Documents: Report

Table of Contents

The Team

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Structural Calculations

All structural calculations were completed using Microsoft Excel, ASCE 7-22, NDS 2018, and SDPWS 2021. The design follows Allowable Stress Design (ASD) specifications. Gravity design includes:

- Cantilever beam design (shear and bending)
- Cantilever beam deflection

Seismic and wind design includes:

- Roof diaphragm design (in-plane shear only)
- Floor diaphragm design (in-plane shear only)
- Shear wall design (in-plane shear and overturning)
- Factor of Safety for the diaphragm and shear walls
- Roof joist anchorage for uplift wind load

Additionally, the calculations include:

- The total predicted weight of the structure
- Additional calculations for the completion of the structure

Cantilever beam design and deflection

Cantilever Beam Info:			
PL	=	150	lbs
M	=	600	lb-ft @ wall
L	=	4	ft
Lateral support only at end			
Try:			
2x6 DF-L No. 2			
l(u)	=	4	ft
d	=	5.5	in
b	=	1.5	in
Emin	=	580000	psi
Sx	=	7.56	in^3
Fb	=	0.9	ksi
c	=	0.95	
Find:			
Is the design adequate?			
Calculations:			
l(u)/d	=	(4*12)/5.5	
	=	8.727	>7
Thus:			
l(e)	=	1.37(l(u))+3d	
	=	1.37(4*12)+3(5.5)	
	=	82.260	in
	=	6.855	ft
R(B)	=	√l(e)*d/b^2	
	=	√115.14*5.5/1.5^2	
	=	14.180	
F(bE)	=	1.2(Emin')/R(B)^2	
Emin'	=	Emin(C(M)C(t)C(i)C(T))	
	=	580*1	
	=	580.000	ksi
F(bE)	=	(1.2(160000))/(16.78^2)	
	=	3.461	ksi
Fb*	=	Fb(C(D)C(M)C(t)C(fu)C(i)C(T))	
	=	0.99*1.17*1.3	
	=	1.369	ksi

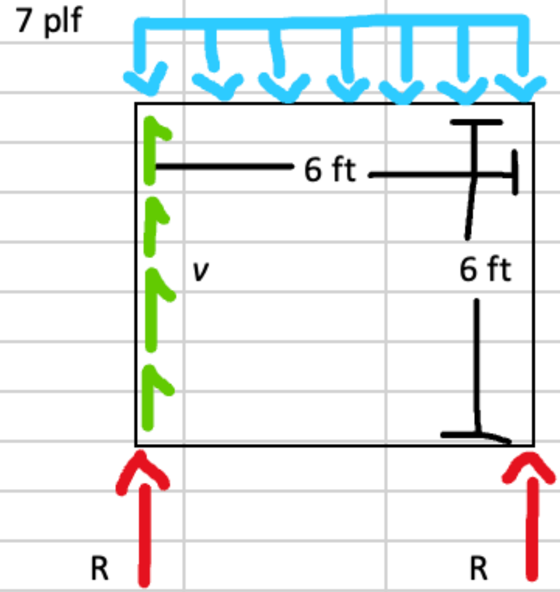
α	=	F(bE)/Fb*	
	=	3.46/1.053	
	=	2.529	
C(L)	=	(1+α)/2c - √((1+α)/2c)^2	
		- α/c)	
	=	(1+2.5)/1.9 - √((1+2.5)/1.9)^2	
		- 2.5/0.95)	
	=	0.970	
Fb'	=	Fb*(C(L))	
	=	1.053*0.98	
	=	1.328	ksi
M(all)	=	Fb'(Sx)	
	=	1.03*7.56	
	=	10.037	kip-in
	=	0.836	kip-ft
OK?	=	TRUE	
Deflection:			
Δ	=	PL^3/3EI	
	=	150(4^3)/(3*580000*20.8)	
	=	0.458	in
Conclusion:			
The beam will likely deflect more in practice, bringing it to 0.5". Additionally, a smaller beam is unable to support the applied load with the available flexural strength. Thus, use (1) 2x6 beam.			

Roof diaphragm design

The decision was made to use the same diaphragm at the mid-level floor and roof levels for the sake of simplicity and constructability. The following calculations apply the most conservative case, (e.g. highest loads), for either diaphragm, and will be repeated in the “Floor diaphragm design” section for the sake of completion.

Roof and Floor Diaphragms:			
EQ(roof)	=	275	plf
EQ(floor)	=	225	plf
WL	=	180	plf
L	=	6	ft
W	=	6	ft
H(tot)	=	12	ft
Try:			
Panels	=	7/16" OSB shtg	
Blocking	=	Unblocked	
AR	=	3	
Use NDS SDPWS Table 4.2C			
v(s, EQ)	=	340	plf
Ga	=	5.5	kips/in
v(w, WL)*	=	475	plf
Nails	=	8d	
Spac	=	6	in o.c.
FS	=	1.77	
Find:			
Is the design adequate?			
Calculations:			
1) Check aspect ratio			
L/W	=	6/6	
	=	1.000	
OK?	=	TRUE	(1<3)
2) Check nail spacing and blocking			
Transverse and longitudinal directions are the same.			
Roof and floor are also the same.			
Both directions:			
0.7(EQ)	=	0.7(10)	
	=	192.500	plf

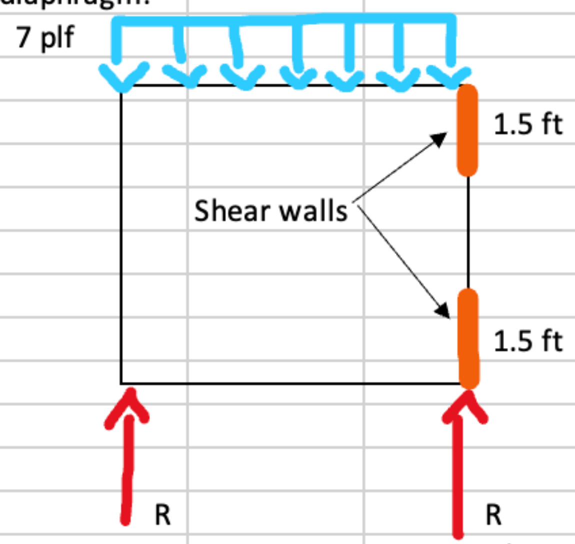
Idealize the diaphragm as a simply-supported beam:



R	=	EQ(L)/2	
	=	7(6)/2	
	=	577.500	lbs
Demand:			
v(a)	=	R/W	
	=	472.5/6	
	=	96.250	plf
Capacity:			
v(all)	=	v(s, EQ)/FS	
	=	220/2	
	=	170.000	plf
OK?	=	TRUE	(110>3.5)
3) Calculate max chord force			
Assume continuous top plate			
M	=	EQ(L^2)/8	
	=	7(6^2)/8	
	=	866.250	lb-ft
F	=	M/d	
	=	31.5/6	
	=	144.375	lbs
Design top plate splice for:		144.375	lbs

4) Calculate lateral force transfer to shear walls

Assume all walls are shear walls, and a flexible diaphragm.



F	=	R(L(SW1)/(L(SW,tot))	
	=	21(1.5/3)	
	=	288.750	lbs
Design shear walls for:		10.500	lbs
5) Deflection			
Midspan deflection, no splice			
Assume the top plate is:			
2x6 DF-L No. 2			
E	=	1600000	psi
A	=	16.5	in^2
x	=	0.054	in
δ	=	δ(flex)+δ(shear)+δ(chord)	
δ(flex)	=	5(v(a)*l^3)/8EAW	
	=	5(3.5*(6^3))/8(**E**	
		(2*2.5*5.5)6	
	=	8.20313E-05	in
δ(shear)	=	0.25(v(a)*l)/1000(G(a))	
	=	0.25*(3.5*6)/1000*6	
	=	0.02625	in
δ(chord)	=	∑(x*Δc)/2W	
	=	∑(**x***2*(6))/2(6)	
	=	0.054	in
δ	=	0.00008+0.02+0.05	
δ	=	0.0803	in

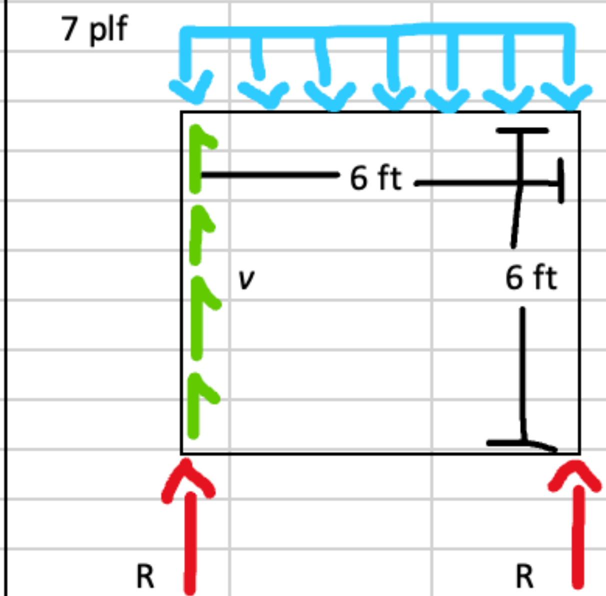
6) Factor of Safety			
FS(dia)	=	*v(all)/v(a)*	
	=	170/96.25	
FS(dia)	=	1.77	
Conclusion:			
For the diaphragm, use unblocked 7/16" OSB sheathing			
with 8d nails at 6" o.c. for a factor of safety of 1.77.			
Let joists be 24" o.c. This will work for both the floor			
and roof, as the conservative case was taken in			
the diaphragm calculations.			

Floor diaphragm design

The decision was made to use the same diaphragm at the mid-level floor and roof levels for the sake of simplicity and constructability. The following calculations apply the most conservative case, (e.g. highest loads), for either diaphragm, and are a repetition of the calculations found in “Roof diaphragm design” for the sake of completion.

Roof and Floor Diaphragms:			
EQ(roof)	=	275	plf
EQ(floor)	=	225	plf
WL	=	180	plf
L	=	6	ft
W	=	6	ft
H(tot)	=	12	ft
Try:			
Panels	=	7/16" OSB shtg	
Blocking	=	Unblocked	
AR	=	3	
Use NDS SDPWS Table 4.2C			
v(s, EQ)	=	340	plf
Ga	=	5.5	kips/in
v(w, WL)*	=	475	plf
Nails	=	8d	
Spac	=	6	in o.c.
FS	=	1.77	
Find:			
Is the design adequate?			
Calculations:			
1) Check aspect ratio			
L/W	=	6/6	
	=	1.000	
OK?	=	TRUE	(1<3)
2) Check nail spacing and blocking			
Transverse and longitudinal directions are the same.			
Roof and floor are also the same.			
Both directions:			
0.7(EQ)	=	0.7(10)	
	=	192.500	plf

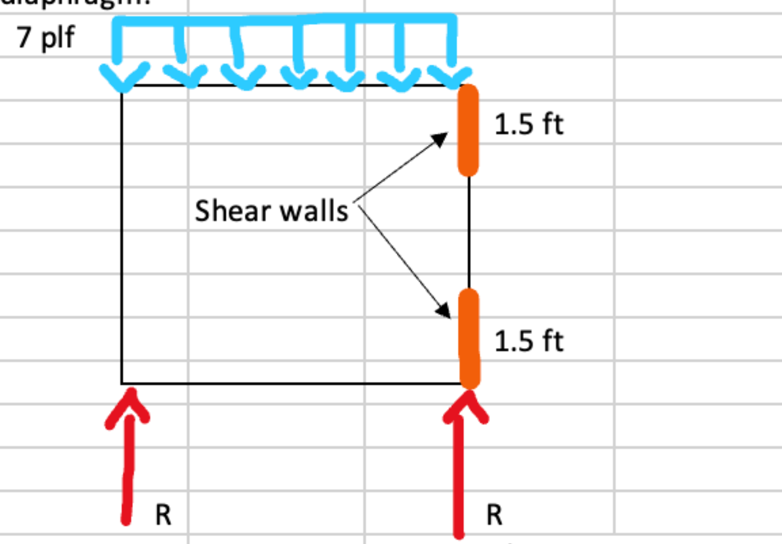
Idealize the diaphragm as a simply-supported beam:



R	=	EQ(L)/2	
	=	7(6)/2	
	=	577.500	lbs
Demand:			
v(a)	=	R/W	
	=	472.5/6	
	=	96.250	plf
Capacity:			
v(all)	=	v(s, EQ)/FS	
	=	220/2	
	=	170.000	plf
OK?	=	TRUE	(110>3.5)
3) Calculate max chord force			
Assume continuous top plate			
M	=	EQ(L^2)/8	
	=	7(6^2)/8	
	=	866.250	lb-ft
F	=	M/d	
	=	31.5/6	
	=	144.375	lbs
Design top plate splice for:		144.375	lbs

4) Calculate lateral force transfer to shear walls

Assume all walls are shear walls, and a flexible diaphragm.



F	=	R(L(SW1)/(L(SW,tot))	
	=	21(1.5/3)	
	=	288.750	lbs
Design shear walls for:		10.500	lbs
5) Deflection			
Midspan deflection, no splice			
Assume the top plate is:			
2x6 DF-L No. 2			
E	=	1600000	psi
A	=	16.5	in^2
x	=	0.054	in
δ	=	δ(flex)+δ(shear)+δ(chord)	
δ(flex)	=	5(v(a)*l^3)/8EAW	
	=	5(3.5*(6^3))/8(**E**	
		(2*2.5*5.5)6	
	=	8.20313E-05	in
δ(shear)	=	0.25(v(a)*l)/1000(G(a))	
	=	0.25*(3.5*6)/1000*6	
	=	0.02625	in
δ(chord)	=	∑(x***Δ**c)/2W	
	=	∑(**x***2*(6))/2(6)	
	=	0.054	in
δ	=	0.00008+0.02+0.05	
δ	=	0.0803	in

6) Factor of Safety			
FS(dia)	=	*v(all)/v(a)*	
	=	170/96.25	
FS(dia)	=	1.77	
Conclusion:			
For the diaphragm, use unblocked 7/16" OSB sheathing			
with 8d nails at 6" o.c. for a factor of safety of 1.77.			
Let joists be 24" o.c. This will work for both the floor			
and roof, as the conservative case was taken in			
the diaphragm calculations.			

Shear wall design

Shear Walls:			
DL(roof)	=	6.91375	plf
LL(roof)	=	20	psf
	=	60	plf
DL(floor)	=	13.8275	plf
LL(floor)	=	50	psf
	=	150	plf
EQ(roof)	=	275	plf
EQ(floor)	=	225	plf
H1	=	5	ft
H2	=	7	ft
Use a segmented shear wall approach			
w	=	2	ft
Try:			
7/16" OSB Structural 1 panels			
8d nails, s	=	6	in o.c.
Find:			
An adequate design			
Calculations:			
1) Check shear wall aspect ratio			
Tallest wall controls. Thus:			
AR	=	h/w	
	=	7/2	
	=	3.500	<3.5, OK
ARF reduction needed, because 3.5>2.			
WSP	=	1.25-(0.125*AR)	
	=	1.25-(0.125*3.5)	
	=	0.813	
2) Check shear strength			
1st story:			
v(a)	=	(0.7*(EQ(roof)+EQ(floor)))/w	
	=	(0.7*(275+225))/2	
	=	175.000	plf
v(all)	=	v(s)/2	
	=	(670/2)*WSP	
	=	272.188	plf
OK?	=	TRUE	
FS	=	*v(all) /v(a)*	
	=	272.19/175	
FS(1)	=	1.555	

2nd story:			
v(a)	=	(0.7*(EQ(roof))/w	
	=	(0.7*(275))/2	
	=	96.250	plf
v(all)	=	v(s)/2	
	=	(670/2)*WSP	
	=	272.188	plf
OK?	=	TRUE	
FS	=	*v(all) /v(a)*	
	=	272.19/96.25	
FS(2)	=	2.828	
FS(avg)	=	(FS(1)+FS(2))/2	
	=	(1.56+2.83)/2	
FS(avg)	=	2.192	
3) Required hold-down force at foundation			
T	=	0.7(EQ(roof))(H1+H2)+0.7(EQ(floor)H1	
	=	0.7(275)(5+7)+0.7(225)(5)	
	=	3097.500	lbs
T	=	3.098	kips
4) Required distributed anchorage strength			
v(req)	=	*v(a,max)*	
v(req)	=	175.000	plf

5) Determine if end post is adequate			
1st story:			
P(a)	=	(DL+LL)*(L/2)	
	=		
	=	163.828	lbs
	=	0.164	kips
P(all)	=	1.641	kips
OK?	=	TRUE	
2nd story:			
P(a)	=	(DL+LL)*(L/2)	
	=		
	=	66.914	lbs
	=	0.067	kips
P(all)	=	0.871	kips
OK?	=	TRUE	
Conclusion:			

Based on the hold-down and anchorage strength requirement calculations, it will be suffiecient to use STHD14 hold-downs at the foundation and LSTA18 ties at the floor level. For anchorage, PAB4-12 anchor bolts with 3/8 x 1 1/2 x plate washers can be used at every 6" o.c. at the foundation level.

Factors of safety

Factor of safety calculations are included in their respective diaphragm and shear wall calculations. However, they are restated here for the sake of completion. To see the calculations supporting the capacity and demand values used in calculating the factors of safety, please reference the "Shear wall design," "Floor diaphragm design," and "Roof diaphragm design" sections above.

Shear Wall Factors of Safety:			
Level 1:			
FS	=	v(all)/v(a)	
	=	272.19/175	
FS(1)	=	1.555	
Level 2:			
FS	=	v(all)/v(a)	
	=	272.19/96.25	
FS(2)	=	2.828	
Average:			
FS(avg)	=	(FS(1)+FS(2))/2	
	=	(1.56+2.83)/2	
FS(avg)	=	2.192	
Diaphragm Factors of Safety:			
Level 1 (floor):			
FS(1)	=	v(all)/v(a)	
	=	170/96.25	
FS(1)	=	1.766	
Level 2 (roof):			
FS(2)	=	v(all)/v(a)	
	=	170/96.25	
FS(2)	=	1.766	
Average:			
FS(avg)	=	(FS(1)+FS(2))/2	
	=	(1.77+1.77)/2	
FS(avg)	=	1.766	

Roof joist anchorage

Roof Joist Anchorage:			
Uplift	=	30	psf
Find:			
The anchorage required to resist uplift			
Calculations:			
Assume:			
s (spacing)	=	6	ft
Thus:			
A(trib)	=	3*6	
	=	18	ft^2
Uplift	=	A(trib)*Uplift	
	=	18*30	
	=	540	lbs
From the Simpson Strong-Tie Catalogue, for			
H8			
Uplift(max)	=	780	
Applying a factor of 0.75:			
Uplift(cap)	=	585	
OK?	=	TRUE	
Conclusion:			
Use H8 ties, with (5) 0.148 x 1 1/2 fasteners.			

Weight of structure

Total Weight:			
OSB	=	50	pcf
2x6 DF-L	=	2.005	plf
2x8 DF-L	=	2.643	plf
Find:			
Appropriate dead loads and the total structure weight.			
Calculations:			
Dead loads:			
For 5/16" OSB:			
W(OSB)	=	OSB*(thickness)	
	=	50*(5/16)/12	
	=	1.302	psf
For 2x6 DF-L, each side 6' long:			
W(DF-L)	=	1.5(2x6 DF-L)/(trib width)	
	=	1.5(2.005)/(3)	
	=	1.003	psf
DL	=	W(OSB)+W(DF-L)	
	=	1.3+1.0025	
DL(roof)	=	2.305	psf
DL(floor)	=	4.609	psf
Total weight:			
For the floor sheathing, we will require approximately:			
V(OSB, f)	=	n(floors)*area*thickness	
	=	2*6*6*5/16	
	=	1.875	ft^3

For the wall sheathing, we will require approximately:			
V(OSB, w)	=	([n(walls,1)*area,1]+[n(walls,2)	
		*area,2])*thickness	
	=	([4*5*6]+[4*7*6])*(7/16)	
	=	10.500	ft^2
Thus, our total sheathing weight is:			
W(shtg)	=	OSB*(V(OSB, f)+V(OSB, w))	
	=	50*(1.875+10.500)	
	=	618.750	lbs
For the 2x6 members, we will require approximately:			
L(2x6)	=	(n(length,1)*length,1)+	
		(n(length,2)*length,2)+…	
	=	(6*6)+(1*10)+(12*7)+(12*5)	
	=	190	ft
For the 2x8 members, we will require approximately:			
L(2x6)	=	(n(length,1)*length,1)+	
		(n(length,2)*length,2)+…	
	=	(12*6)	
	=	72	ft
Thus, our total lumber weight is:			
W(lumber)	=	[(2x6 DF-L)*(L(2x6))]+	
		[(2x8 DF-L)*(L(2x8))]	
	=	[2.005*190]+[2.643*72]	
	=	571.246	lbs
Now, our total weight is:			
W(total)	=	W(shtg)+W(lumber)	
	=	618.750+571.246	
	=	1189.996	lbs
W(total)	=	1.190	kips

Additional calculations

First, we have beam and joist calculations carried out to ensure that outer beam members and joists will be sufficient:

Beams and Joists:			
Beams:			
LL(roof)	=	20	psf
	=	60	plf
DL(roof)	=	6.91	plf
LL(floor)	=	50	psf
	=	150	plf
DL(floor)	=	13.83	plf
Lateral support only at ends			
Try:			
2x8 DF-L No. 2			
l(u)	=	6	ft
d	=	7.25	in
b	=	1.5	in
Emin	=	580000	psi
Sx	=	13.14	in^3
Fb	=	0.9	ksi
c	=	0.95	
Find:			
Is the design adequate?			
Calculations:			
l(u)/d	=	(6*12)/7.25	
	=	9.931	>7
Thus:			
l(e)	=	1.37(l(u))+3d	
	=	1.37(6*12)+3(7.25)	
	=	120.390	in
	=	10.033	ft
R(B)	=	√l(e)*d/b^2	
	=	√120.39*7.25/1.5^2	
	=	19.696	
F(bE)	=	1.2(Emin')/R(B)^2	
Emin'	=	Emin(C(M)C(t)C(i)C(T))	
	=	580*1	
	=	580.000	ksi

F(bE)	=	(1.2(580))/(19.7^2)	
	=	1.794	ksi
Fb*	=	Fb(C(D)C(M)C(t)C(i)C(T))	
	=	0.9*1.17*1.3	
	=	1.369	ksi
α	=	F(bE)/Fb*	
	=	1.79/1.053	
	=	1.311	
C(L)	=	(1+α)/2c - √((1+α)/2c)^2	
		- α/c)	
	=	(1+1.7)/1.9 - √((1+1.7)/1.9)^2	
		- 1.7/0.95)	
	=	0.901	
Fb'	=	Fb*(C(L))	
	=	1.053*0.94	
	=	1.233	ksi
M(all)	=	Fb'(Sx)	
	=	0.99*13.14	
	=	16.206	kip-in
	=	1.350	kip-ft
M(a)	=	wL^2/8	
Roof:			
M(a)	=	((6.91+60)*(6^2))/8	
	=	0.301	kip-ft
Floor:			
M(a)	=	((6.91+150)*(6^2))/8	
	=	0.737	kip-ft
OK?	=	TRUE	
Conclusion:			

To be conservative, the outside beams were checked without the planned-for 2x6 joists. 2x6 joists will be sufficient, and 2x8 outside members will also suffice. Joists are to be spaced at 24" o.c.

Additionally, we have calculations for the posts and studs used in the structure at both the floor and roof levels:

Posts:			
Posts:			
LL(roof)	=	20	psf
P(LL)	=	180	lbs
DL(roof)	=	82.965	lbs
LL(floor)	=	50	psf
P(LL)	=	450	lbs
DL(floor)	=	165.93	lbs
EQ(roof)	=	275	plf
EQ(floor)	=	225	plf
h(1)	=	5	ft
h(2)	=	7	ft
Try:			
2x6 DF-L No. 2			
l(u)	=	5	ft
d	=	5.5	in
b	=	1.5	in
Emin	=	580000	psi
Sx	=	7.56	in^3
Fc	=	0.625	ksi
Fb	=	0.9	ksi
c	=	0.8	
Find:			
An adequate design.			
Calculations:			
Axial Compressive Strength, roof:			
Demand:			
P(a)	=	P(LL, roof)+DL(roof)	
	=	(180+82.96)/1000	
	=	0.263	kips

Capacity:			
Axial Only:			
Fc*	=	Fc[C(D)C(M)C(t)C(F)C(i)]	
	=	0.625*1.15*1	
	=	0.719	ksi
(le/d)x	=	(7*12)/5.5	
	=	15.273	
(le/d)y	=	(7*12)/1.5	
	=	56.000	(Controls)
F(cE)	=	0.822(Emin')/(le/d)^2	
Emin'	=	Emin(C(M)C(t)C(i)C(T))	
	=	580*1.15	
	=	667.000	ksi
F(cE)	=	0.822*667/56^2	
	=	0.175	ksi
α	=	F(cE)/Fc*	
	=	0.17/0.71	
	=	0.243	
Cp	=	(1+α)/2c - √((1+α)/2c)^2	
		- α/c)	
	=	(1+0.24)/1.6 - √((1+0.24)/1.6)^2	
		- 0.24/0.8)	
	=	0.230	
Fc'	=	Fc*(Cp)	
	=	0.71*0.23	
	=	0.165	ksi
P'	=	Fc'(A)	
	=	0.165*1.5*5.5	
	=	1.361	kips
OK?	=	TRUE	
Conclusion:			
Use 2x6 DF-L No. 2 posts. Conservative calculations of tributary area mean that they will be able to withstand the specified loads.			

Axial Compressive Strength, floor:			
Demand:			
P(a)	=	P(LL, roof)+DL(roof)	
	=	(450+165.93)	
	=	0.616	kips
Capacity:			
Axial Only:			
Fc*	=	Fc[C(D)C(M)C(t)C(F)C(i)]	
	=	0.625*1.15*1	
	=	0.719	ksi
(le/d)x	=	(5*12)/5.5	
	=	10.909	
(le/d)y	=	(5*12)/1.5	
	=	40.000	(Controls)
F(cE)	=	0.822(Emin')/(le/d)^2	
Emin'	=	Emin(C(M)C(t)C(i)C(T))	
	=	580*1.15	
	=	667.000	ksi
F(cE)	=	0.822*667/40^2	
	=	0.343	ksi
α	=	F(cE)/Fc*	
	=	0.34/0.71	
	=	0.477	
Cp	=	(1+α)/2c - √((1+α)/2c)^2	
		- α/c)	
	=	(1+0.48)/1.6 - √((1+0.48)/1.6)^2	
		- 0.48/0.8)	
	=	0.417	
Fc'	=	Fc*(Cp)	
	=	0.71*0.42	
	=	0.300	ksi
P'	=	Fc'(A)	
	=	0.3*1.5*5.5	
	=	2.473	kips
OK?	=	TRUE	
Conclusion:			
Use 2x6 DF-L No. 2 posts. Conservative calculations of tributary area mean that they will be able to withstand the specified loads.			

Studs:			
Studs:			
LL(roof)	=	20	psf
P(LL)	=	30	lbs
DL(roof)	=	82.965	lbs
LL(floor)	=	50	psf
P(LL)	=	75	lbs
DL(floor)	=	165.93	lbs
EQ(roof)	=	275	plf
EQ(floor)	=	225	plf
h(1)	=	5	ft
h(2)	=	7	ft
Try:			
2x6 DF-L No. 2			
l(u)	=	5	ft
d	=	5.5	in
b	=	1.5	in
Emin	=	580000	psi
Sx	=	7.56	in^3
Fc	=	0.625	ksi
Fb	=	0.9	ksi
c	=	0.8	
s	=	6	in
	=	0.5	ft
Find:			
An adequate design.			
Calculations:			
Axial Compressive Strength, roof:			
Demand:			
P(a)	=	P(LL, roof)+DL(roof)	
	=	(180+82.96)/1000	
	=	0.263	kips

Capacity:			
Fc*	=	Fc[C(D)C(M)C(t)C(F)C(i)]	
	=	0.625*1.6*1	
	=	1.000	ksi
Axial Only:			
Fc*	=	Fc[C(D)C(M)C(t)C(F)C(i)]	
	=	0.625*1.15*1	
	=	0.719	ksi
(le/d)x	=	(7*12)/5.5	
	=	15.273	
(le/d)y	=	(7*12)/1.5	
	=	56.000	(Controls)
F(cE)	=	0.822(Emin')/(le/d)^2	
Emin'	=	Emin(C(M)C(t)C(i)C(T))	
	=	580*1.15	
	=	580.000	ksi
F(cE)	=	0.822*580/(56^2)	
	=	0.152	ksi
α	=	F(cE)/Fc*	
	=	0.15/1	
	=	0.152	
Cp	=	(1+α)/2c - √((1+α)/2c)^2	
		- α/c)	
	=	(1+0.15)/1.6 - √((1+0.15)/1.6)^2	
		- 0.15/0.8)	
	=	0.147	
Fc'	=	Fc*(Cp)	
	=	1*0.15	
	=	0.147	ksi
P'	=	Fc'(A)	
	=	0.15*1.5*5.5	
	=	1.212	kips

Flexural Strength, roof:			
Demand:			
M(a)	=	wL^2/8	
	=	((275/1000)*7^2)/8	
	=	1.684	kip-ft
Capacity:			
Fb'	=	Fb[C(D)C(M)C(L)C(t)C(F)C(i)C(r)]	
	=	0.9*1.6	
	=	1.440	ksi
M'	=	Fb'(Sx)	
	=	1.44*7.56	
	=	10.886	kip-ft
Combined Flexure and Compression, roof:			
Pa/PcE	=	Pa/(FcE(A))	
	=	0.263/(0.15*1.5*5.5)	
	=	0.210	
Mr	=	M(a) (1/(1-(Pa/PcE))	
	=	1.68(1/(1-(0.21))	
	=	2.131	kip-ft
1	>	(Pa/P')^2 + (Mr/M')	
1	>	(0.26/1.21)^2 + (2.13/10.8)	
1	>	0.243	
OK?	=	TRUE	
Conclusion:			
Use 2x6 DF-L No. 2 studs @ 24" o.c. Conservative calculations of tributary area mean that they will be able to withstand the specified loads.			

Axial Compressive Strength, floor:			
Demand:			
P(a)	=	P(LL, roof)+DL(roof)	
	=	(450+165.93)/1000	
	=	0.616	kips
Capacity:			
Fc*	=	Fc[C(D)C(M)C(t)C(F)C(i)]	
	=	0.625*1.6*1	
	=	1.000	ksi
Axial Only:			
Fc*	=	Fc[C(D)C(M)C(t)C(F)C(i)]	
	=	0.625*1.15*1	
	=	0.719	ksi
(le/d)x	=	(5*12)/5.5	
	=	10.909	
(le/d)y	=	(5*12)/1.5	
	=	40.000	(Controls)
F(cE)	=	0.822(Emin')/(le/d)^2	
Emin'	=	Emin(C(M)C(t)C(i)C(T))	
	=	580*1.15	
	=	580.000	ksi
F(cE)	=	0.822*580/(40^2)	
	=	0.298	ksi
α	=	F(cE)/Fc*	
	=	0.3/1	
	=	0.298	
Cp	=	(1+α)/2c - √((1+α)/2c)^2	
		- α/c)	
	=	(1+0.3)/1.6 - √((1+0.3)/1.6)^2	
		- 0.3/0.8)	
	=	0.277	
Fc'	=	Fc*(Cp)	
	=	1*0.28	
	=	0.277	ksi
P'	=	Fc'(A)	
	=	0.28*1.5*5.5	
	=	2.284	kips

Flexural Strength, floor:			
Demand:			
M(a)	=	wL^2/8	
	=	((275/1000)*7^2)/8	
	=	0.703	kip-ft
Capacity:			
Fb'	=	Fb[C(D)C(M)C(L)C(t)C(F)C(i)C(r)]	
	=	0.9*1.6	
	=	1.440	ksi
M'	=	Fb'(Sx)	
	=	1.44*7.56	
	=	10.886	kip-ft
Combined Flexure and Compression, floor:			
Pa/PcE	=	Pa/(FcE(A))	
	=	0.62/(0.3*1.5*5.5)	
	=	0.251	
Mr	=	M(a) (1/(1-(Pa/PcE))	
	=	0.7(1/(1-(0.251))	
	=	0.938	kip-ft
1	>	(Pa/P')^2 + (Mr/M')	
1	>	(0.62/2.28)^2 + (0.94/10.8)	
1	>	0.159	
OK?	=	TRUE	
Conclusion:			
Use 2x6 DF-L No. 2 studs @ 24" o.c. Conservative calculations of tributary area mean that they will be able to withstand the specified loads.			

Sustainable Design Calculations

In accordance with the Timber Strong Design Build Rules, the carbon footprint of the competition structure was calculated using the recommended calculator found at http://www.woodworks.org/carbon-calculator-download-form/.

Carbon Footprint (1x)

The following images are screen-snips of the inputs and output forms from the WoodWorks carbon calculator. Input values in this section are taken straight from the materials list developed during structural calculations at 1:1 ratio.

Calculations

1. **Construction Type:**

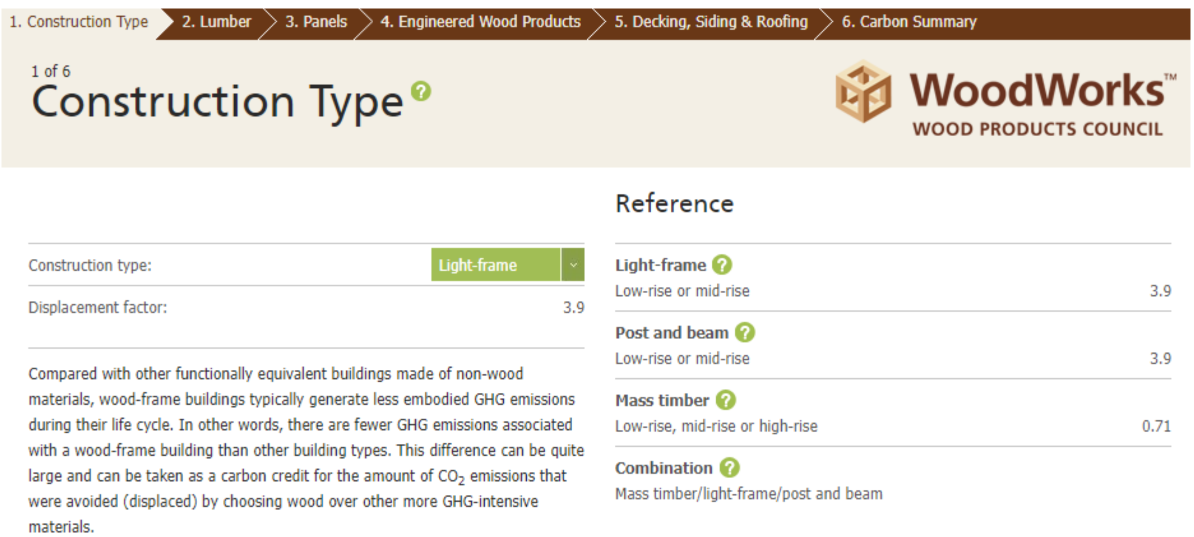


Figure 12: WookWorks Carbon Calculator, Step 1 - Construction Type

2. Lumber:

Figure 13: WookWorks Carbon Calculator, Step 2 - Lumber

3. Panels:

Figure 14: WookWorks Carbon Calculator, Step 3 - Panels

4. Engineered Wood Products

Figure 15: WookWorks Carbon Calculator, Step 4 - Engineered Wood Products

5. Decking, Siding & Roofing

For the purposes of these calculations, this section was left blank because the 5/16” OSB Sheathing input in the Panels step includes a portion used for roofing.

6. Carbon Summary

Carbon Summary

WoodWorks™
WOOD PRODUCTS COUNCIL

Results

Volume of wood products used (m^3):
1 m^3 (19 ft^3) of lumber and sheathing

U.S. and Canadians forests grow this much wood in:
0 seconds

Carbon stored in the wood:
1 metric tons of CO_2

Avoided greenhouse gas emissions:
1 metric tons of CO_2

Total potential carbon benefit:
2 metric tons of CO_2

Equivalent to:

0 cars off the road for a year

Energy to operate **0** homes for a year

Project: BYU ASCE TSDB

Date: January 16, 2023

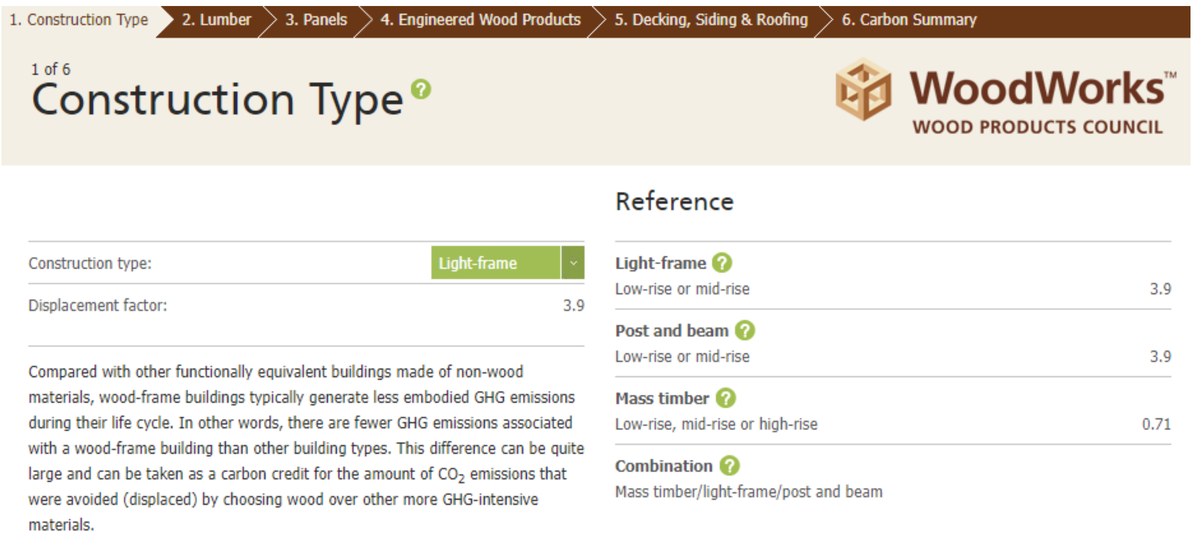
Results from this tool are based on wood volumes only and are estimates of carbon stored within wood products and avoided emissions resulting from the substitution of wood products for non-wood products. The results do not indicate a carbon footprint or global warming potential and are not intended to replace a detailed life cycle assessment (LCA) study. Please refer to the References & Notes (PDF) for assumptions and other information related to the calculations.

Carbon Footprint (100x)

The following images are screen-snips of the inputs and output forms from the WoodWorks carbon calculator. Input values in this section are taken from the materials list developed during structural calculations at 100:1 ratio to simulate the construction of an actual building.

Calculations

1. **Construction Type:**



1. Construction Type | 2. Lumber | 3. Panels | 4. Engineered Wood Products | 5. Decking, Siding & Roofing | 6. Carbon Summary

1 of 6
Construction Type

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Construction type:	Light-frame
Displacement factor:	3.9

Compared with other functionally equivalent buildings made of non-wood materials, wood-frame buildings typically generate less embodied GHG emissions during their life cycle. In other words, there are fewer GHG emissions associated with a wood-frame building than other building types. This difference can be quite large and can be taken as a carbon credit for the amount of CO_2 emissions that were avoided (displaced) by choosing wood over other more GHG-intensive materials.

Reference

Light-frame Low-rise or mid-rise	3.9
Post and beam Low-rise or mid-rise	3.9
Mass timber Low-rise, mid-rise or high-rise	0.71
Combination Mass timber/light-frame/post and beam	

Figure 16: WookWorks Carbon Calculator, Step 1 - Construction Type

2. Lumber:

1. Construction Type > 2. Lumber > 3. Panels > 4. Engineered Wood Products > 5. Decking, Siding & Roofing > 6. Carbon Summary

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Lumber

bf	board feet
lf	linear feet
ft³	cubic feet
m³	cubic meters

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Lumber

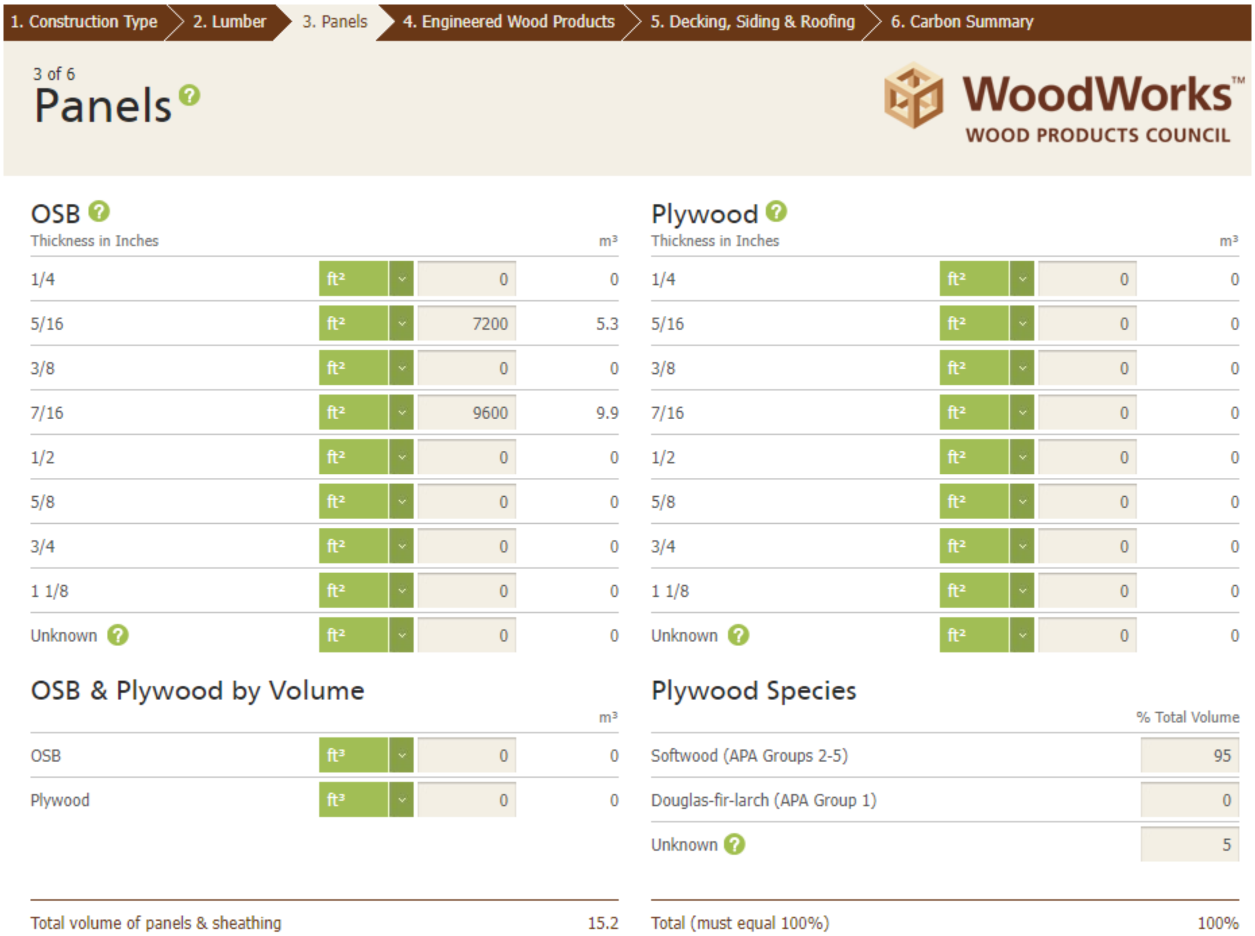
	Unit	Quantity	m³
2x4 (nominal)	lf	0	0
2x6 (nominal)	lf	23800	38.6
2x8 (nominal)	lf	0	0
2x10 (nominal)	lf	0	0
3x3 (nominal)	lf	0	0
4x4 (nominal)	lf	0	0
3x6 (nominal)	lf	0	0
4x6 (nominal)	lf	0	0
Unknown or varied (actual dimensions)	ft³	0	0
Total volume of dimensional lumber			38.6

Lumber Species

	% Total Volume
Spruce-pine-fir	0
Douglas-fir-larch	100
Hemlock-fir	0
Cedar	0
Southern pine	0
Unknown	0
Total (must equal 100%)	100%

Figure 17: WookWorks Carbon Calculator, Step 2 - Construction Type

3. Panels:


1. Construction Type > 2. Lumber > 3. Panels > 4. Engineered Wood Products > 5. Decking, Siding & Roofing > 6. Carbon Summary

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Panels

WoodWorks™ WOOD PRODUCTS COUNCIL

OSB

Thickness in Inches	Unit	Quantity	m³
1/4	ft²	0	0
5/16	ft²	7200	5.3
3/8	ft²	0	0
7/16	ft²	9600	9.9
1/2	ft²	0	0
5/8	ft²	0	0
3/4	ft²	0	0
1 1/8	ft²	0	0
Unknown	ft²	0	0

Plywood

Thickness in Inches	Unit	Quantity	m³
1/4	ft²	0	0
5/16	ft²	0	0
3/8	ft²	0	0
7/16	ft²	0	0
1/2	ft²	0	0
5/8	ft²	0	0
3/4	ft²	0	0
1 1/8	ft²	0	0
Unknown	ft²	0	0

OSB & Plywood by Volume

	Unit	Quantity	m³
OSB	ft³	0	0
Plywood	ft³	0	0
Total volume of panels & sheathing			15.2

Plywood Species

	% Total Volume
Softwood (APA Groups 2-5)	95
Douglas-fir-larch (APA Group 1)	0
Unknown	5
Total (must equal 100%)	100%

Figure 18: WookWorks Carbon Calculator, Step 3 - Lumber

4. Engineered Wood Products

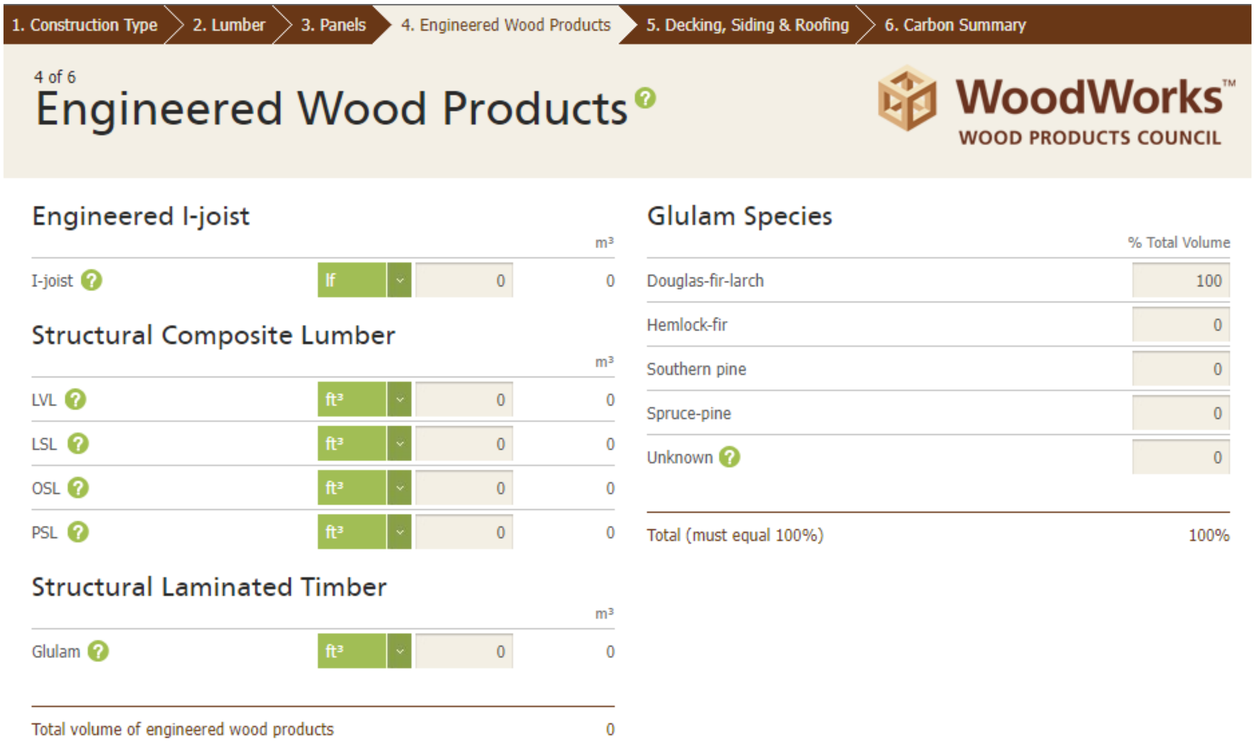


Figure 19:L WookWorks Carbon Calculator, Step 4 - Engineered Wood Products

5. Decking, Siding & Roofing

For the purposes of these calculations, this section was left blank because the 5/16" OSB Sheathing input in the Panels step includes a portion used for roofing.

6. **Carbon Summary**

Carbon Summary

WoodWorks™
WOOD PRODUCTS COUNCIL

Results

Volume of wood products used (m³):
54 m³ (1900 ft³) of lumber and sheathing

U.S. and Canadians forests grow this much wood in:
9 seconds

Carbon stored in the wood:
50 metric tons of CO_2

Avoided greenhouse gas emissions:
107 metric tons of CO_2

Total potential carbon benefit:
157 metric tons of CO_2

Equivalent to:

33 cars off the road for a year

Energy to operate **17** homes for a year

Project: BYU ASCE TSDB

Date: January 16, 2023

Results from this tool are based on wood volumes only and are estimates of carbon stored within wood products and avoided emissions resulting from the substitution of wood products for non-wood products. The results do not indicate a carbon footprint or global warming potential and are not intended to replace a detailed life cycle assessment (LCA) study. Please refer to the References & Notes (PDF) for assumptions and other information related to the calculations.

Sustainability Notes

As mentioned in the Carbon Summary provided by WookWorks, many assumptions are made in the calculation of the stored carbon and avoided emissions. These, and other information, are found in the *References and Notes* found at one of the following links:

- https://cc.woodworks.org/calculator.php?country=us# (bottom of page)
- https://byu.box.com/s/bn2clbxmfcnkyojkxk02wcp7tl8nrpqe (BYU ASCE TSDB shared link)

Budget

From materials and members derived in structural calculations and basic, this budget was developed in Microsoft Excel. The Simpson Catalogue was used for official reference.

Table 1: Budget Calculations

Material	Number Required	Number Purchased	Cost per Unit	Cost of Material	Notes
7' DF-L No. 2 2x6	16	24	$ 9.72	$ 233.28	
5' DF-L No. 2 2x6	16	24	$ 12.44	$ 149.28	*cut 10' in 2
10' DF-L No. 2 2x6	1	2	$ 12.44	$ 24.88	
6' DF-L No. 2 2x6	6	9	$ 9.72	$ 43.74	*cut 12' in 2
6' DF-L No. 2 2x8	12	18	$ 14.96	$ 134.64	*cut 12' in 2
subfloor adhesive	2	3	$ 2.97	$ 8.91	
5/16" OSB shtg	3	5	$ 12.00	$ 60.00	72 ft2 req
*7/16" OSB Structural I shtg	4	6	$ 12.00	$ 72.00	96 ft2 req
6d common nails	192 nails	2	$ 7.27	$ 14.54	
8d common nails	192 nails	3	$ 7.27	$ 21.81	
STHD14 hold downs	8	9	$ 21.35	$ 192.15	
LSTA18 tie downs	8	9	$ 1.42	$ 12.78	
PAB4-12 anchor bolts	48	52	$ 18.98	$ 493.48	
**H8 hurricane ties	6	9	$ 0.78	$ 7.02	
**0.148 x 1 1/2 fasteners	60	1	$ 4.88	$ 4.88	
16d common nails		1	$ 39.98	$ 39.98	

Table 2: Reference Links for Budget

Cost Reference
https://www.homedepot.com/p/2-in-x-6-in-x-8-ft-2-and-Better-Prime-Douglas-Fir-Lumber-2023-8/206019463
https://www.homedepot.com/p/2-in-x-6-in-x-10-ft-Better-Prime-Douglas-Fir-Lumber-2023-10/206019464
https://www.homedepot.com/p/2-in-x-6-in-x-12-ft-2-and-Better-Prime-Douglas-Fir-Lumber-2023-12/206019465
https://www.homedepot.com/p/Liquid-Nails-Subfloor-and-Deck-28-oz-Tan-Low-VOC-Construction-Adhesive-LNP-902/202203997
https://www.homedepot.com/p/OSB-7-16-in-Sheathing-Panel-Application-as-4-ft-x-8-ft-386081/202106229
https://www.homedepot.com/p/OSB-7-16-in-Sheathing-Panel-Application-as-4-ft-x-8-ft-386081/202106230
https://www.homedepot.com/p/Grip-Rite-11-1-2-x-2-in-6-Penny-Hot-Galvanized-Steel-Common-Nails-1-lb-Pack-6HGC1/202308522
https://www.homedepot.com/p/Grip-Rite-10-1-4-x-2-1-2-in-8-Penny-Hot-Galvanized-Steel-Common-Nails-1-lb-Pack-8HGC1/202308496
https://www.homedepot.com/p/Simpson-Strong-Tie-STHD-26-1-8-in-12-Gauge-Galvanized-Strap-Tie-Holdown-STHD14/203302206
https://www.homedepot.com/p/Simpson-Strong-Tie-LSTA-1-1-4-in-x-18-in-20-Gauge-Galvanized-Strap-Tie-LSTA18/100375025
https://www.lowes.com/pd/Simpson-Strong-Tie-RFB-5-8-in-x-12-in-Hot-Dip-Galvanized-Retrofit-Bolt-2-Qty/1002748676
https://www.homedepot.com/p/Simpson-Strong-Tie-H8-18-Gauge-Galvanized-Hurricane-Tie-H8/100375232
https://www.homedepot.com/p/Simpson-Strong-Tie-Strong-Drive-1-1-2-in-x-0-148-in-SCN-Smooth-Shank-HDG-Connector-Nail-120-Pack-N10DHDG-R/206101770
https://www.lowes.com/pd/Hitachi-3-1-4-Inch-Full-Round-Head-Bright-Basic-Plastic-Strip-Nails-Metabo-HPT-20111SHPT/5001962777

Statement on Removal and Donation

After the conclusion of the ASCE Intermountain Southwest Symposium, (ISWS), on April 15, 2023, the structure will be disassembled for transport back to Provo, Utah. Once there, it will be further disassembled for donation to Habitat of Humanity's "Habitat ReStore" program. The materials will, specifically, be donated to the Orem, Utah branch at 340 S Orem Blvd, Orem, UT, 84058. Habitat ReStore provides building materials for a reasonable price, and keeps these materials out of landfills. Additionally, materials are given the opportunity for a "second life" through resale at Habitat ReStore.

Statement on Rules and Safety

All team members have read and understand the rules, including Section 4.5 SAFETY in the ASCE Timber Strong Design-Build Competition Rules 2023 in addition to the referenced OSHA and CAL/OSHA documents.

Ladder Safety Certificates of Completion

Certificate of Completion

is hereby granted to:

Emma Kratz

to confirm that they have completed

Articulated Ladder Safety

1/10/2023

Score: 95

AMERICAN LADDER INSTITUTE

LADDER SAFETY TRAINING

www.laddersafety.org

Certificate of Completion

is hereby granted to:

Steven Okelberry

to confirm that they have completed

Articulated Ladder Safety

1/13/2023

Score: 100

AMERICAN LADDER INSTITUTE

LADDER SAFETY TRAINING

www.laddersafety.org

Certificate of Completion

is hereby granted to:

Ava Pfeil

to confirm that they have completed

Articulated Ladder Safety

1/13/2023

Score: 95

LADDER SAFETY TRAINING
www.laddersafety.org

Certificate of Completion

is hereby granted to:

Nathan Porter

to confirm that they have completed

Articulated Ladder Safety

12/28/2022

Score: 100

AMERICAN LADDER INSTITUTE

LADDER SAFETY TRAINING

www.laddersafety.org

Certificate of Completion

is hereby granted to:

Savannah Thomsen

to confirm that they have completed

Articulated Ladder Safety

1/11/2023

Score: 95

AMERICAN LADDER INSTITUTE

LADDER SAFETY TRAINING
www.laddersafety.org

Signatures

We, the faculty advisor and team captain for this project, hereby certify that the information in this report is valid and complete to the best of our knowledge.

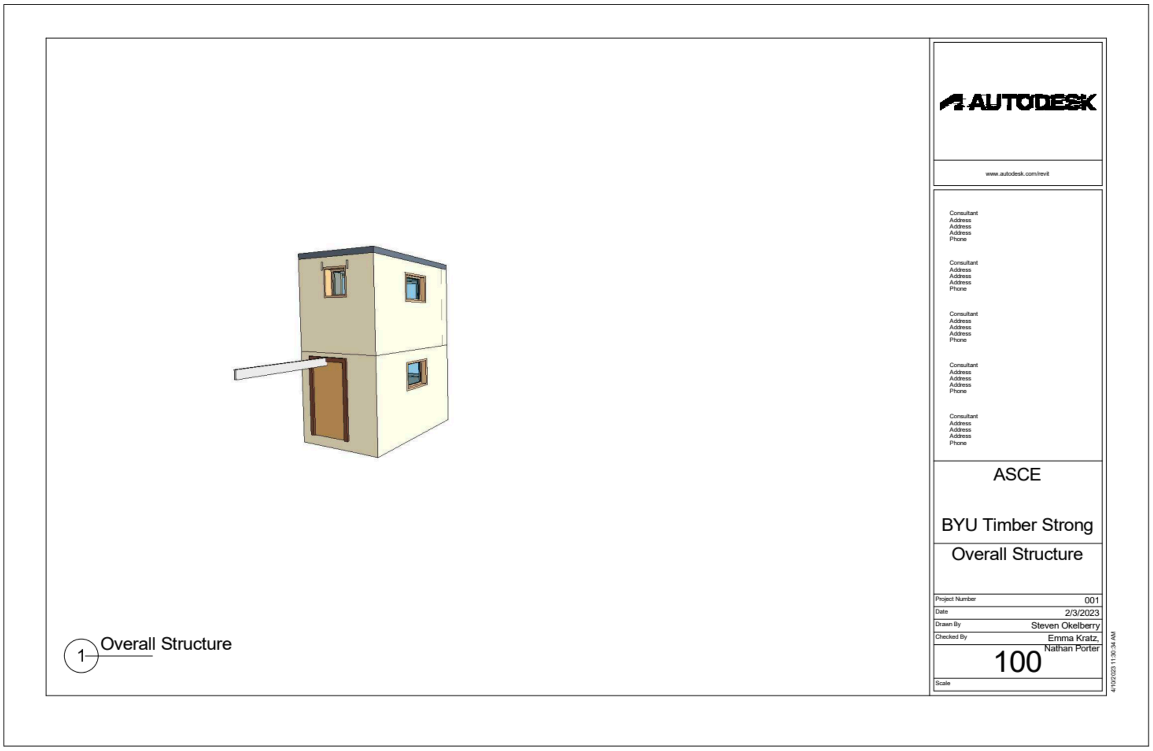
Dr. Kevin Franke, Faculty Advisor

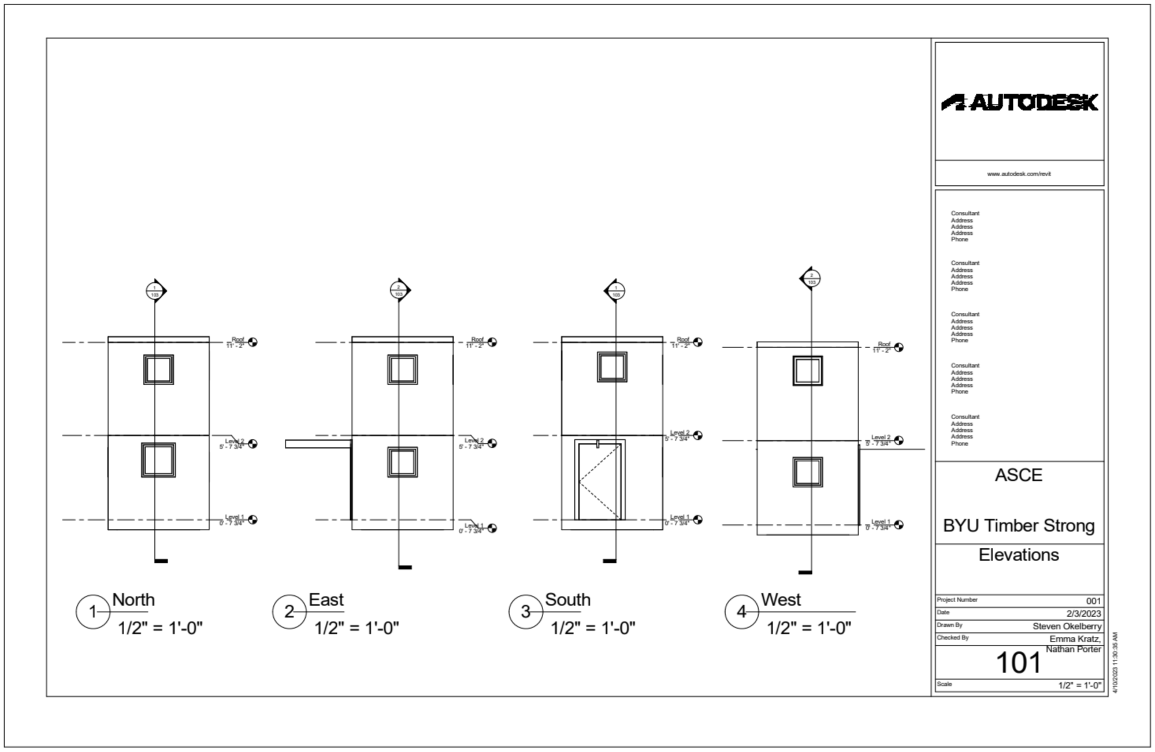
1/16/23
Date

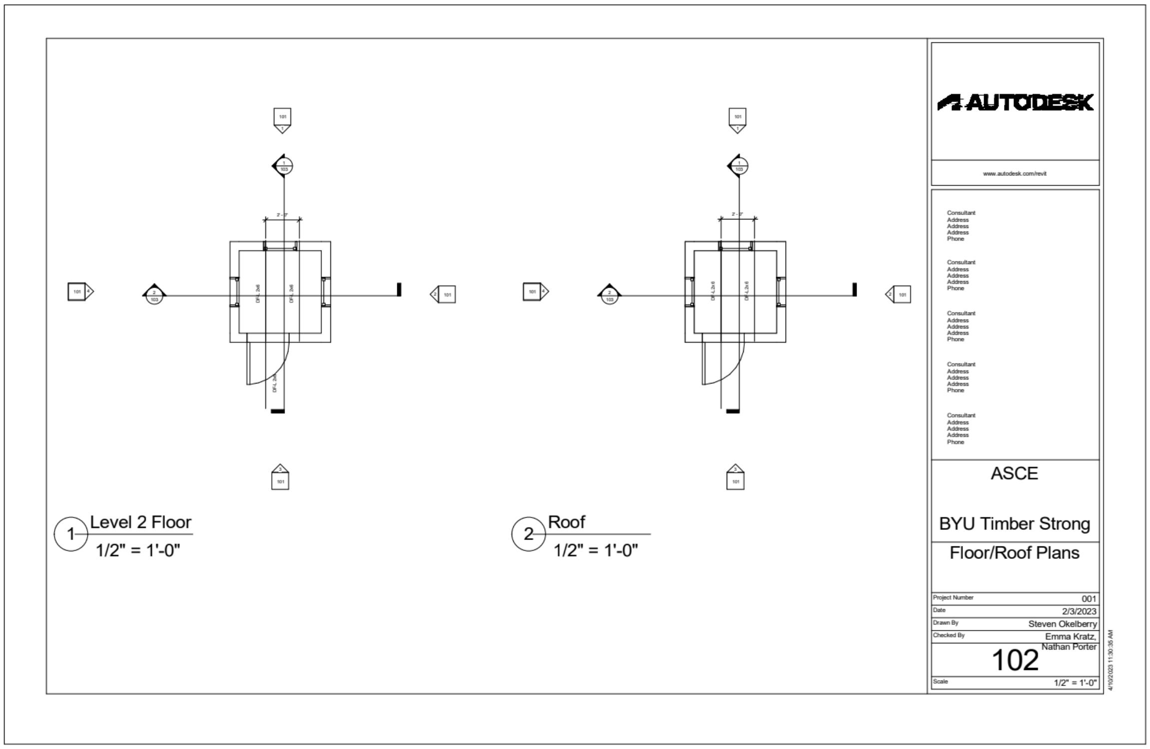
Emma Kratz-Bailey, Team Captain

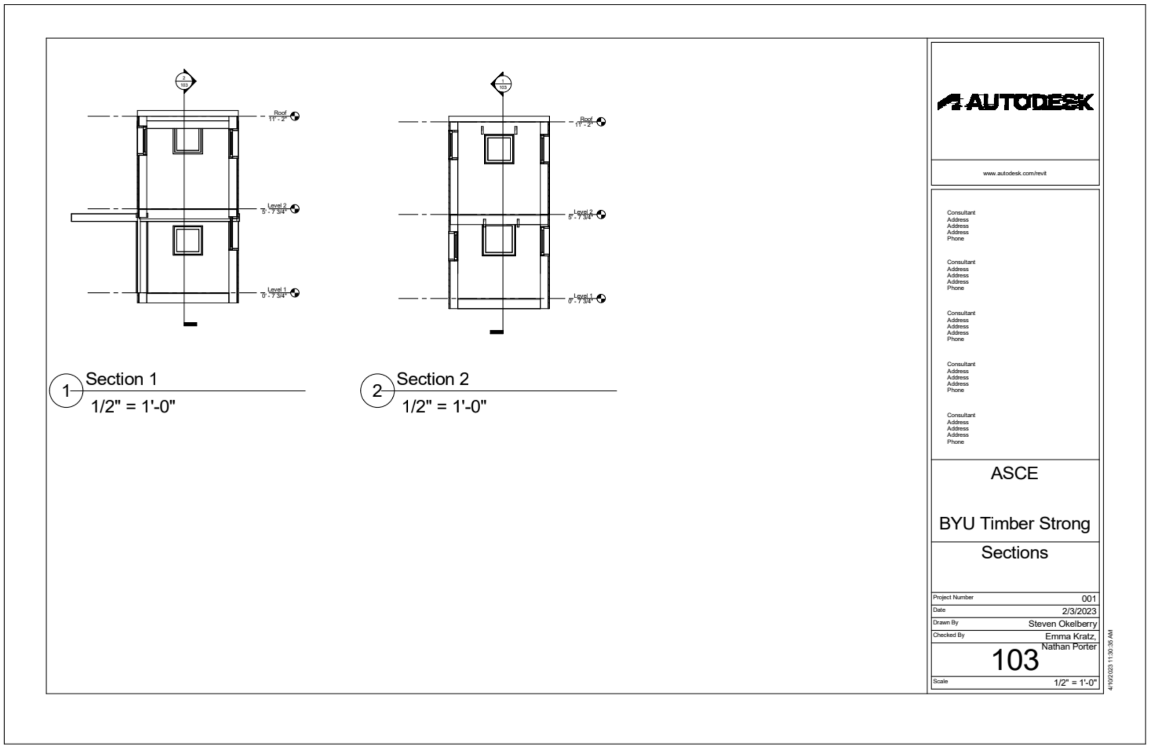
1/16/2023
Date

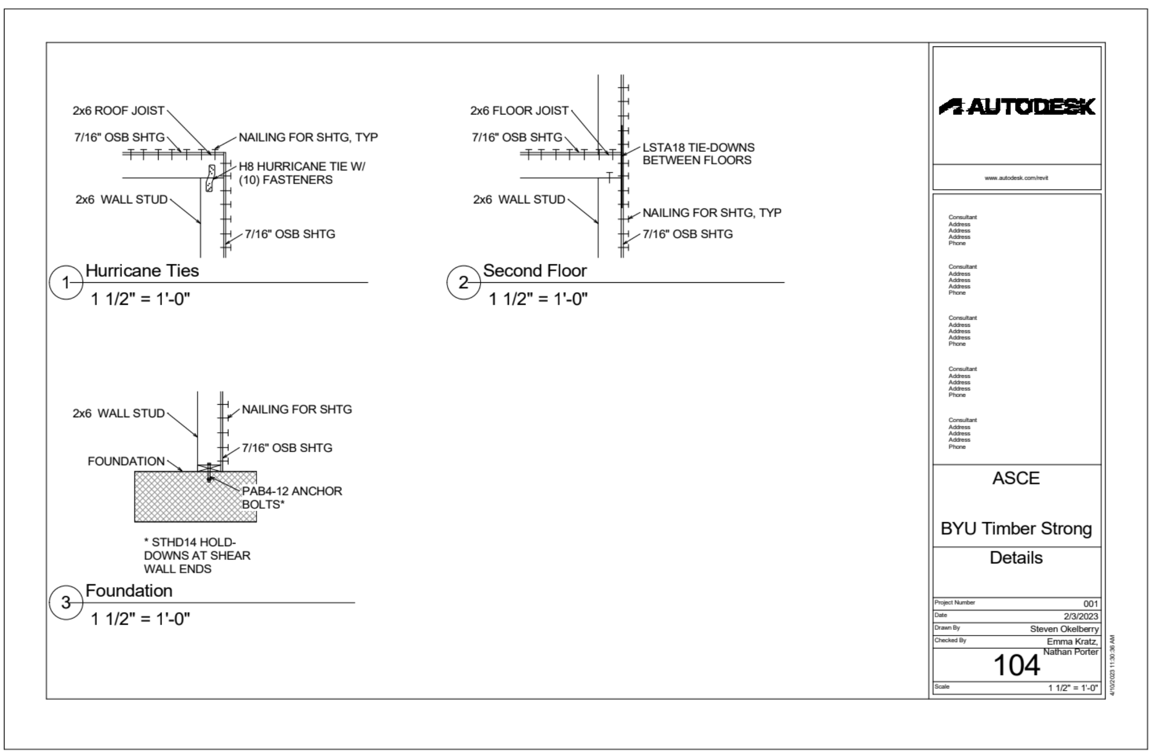
Appendix D: Phase 2 Drawings and Framing Plans



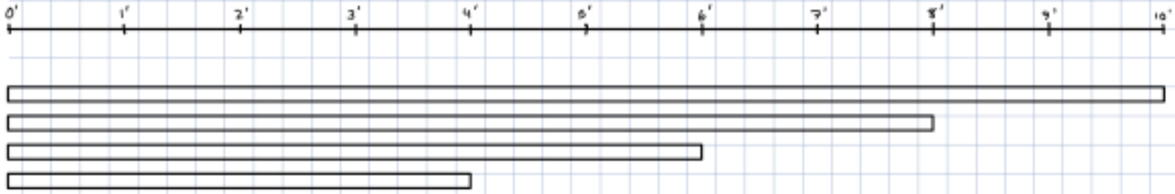

AUTODESK
www.autodesk.com/revit
ASCE
BYU Timber Strong
Elevations
Project Number 001
Date 2/3/2023
Drawn By Steven Okelberry
Checked By Emma Kratz, Nathan Porter
101
Scale 1/2" = 1'-0"
North
1/2" = 1'-0"
East
1/2" = 1'-0"
South
1/2" = 1'-0"
West
1/2" = 1'-0"


AUTODESK
www.autodesk.com/revit
ASCE
BYU Timber Strong
Floor/Roof Plans
Project Number 001
Date 2/3/2023
Drawn By Steven Okelberry
Checked By Emma Kratz, Nathan Porter
102
Scale 1/2" = 1'-0"
Level 2 Floor
1/2" = 1'-0"
Roof
1/2" = 1'-0"


Section 1
1/2" = 1'-0"
Section 2
1/2" = 1'-0"
AUTODESK
ASCE
BYU Timber Strong
Sections
Project Number 001
Date 2/3/2023
Drawn By Steven Okelberry
Checked By Emma Kratz, Nathan Porter
103
Scale 1/2" = 1'-0"


2x6 ROOF JOIST
7/16" OSB SHTG
NAILING FOR SHTG, TYP
H8 HURRICANE TIE W/ (10) FASTENERS
2x6 WALL STUD
7/16" OSB SHTG
Hurricane Ties
1 1/2" = 1'-0"
2x6 FLOOR JOIST
7/16" OSB SHTG
LSTA18 TIE-DOWNS BETWEEN FLOORS
2x6 WALL STUD
NAILING FOR SHTG, TYP
7/16" OSB SHTG
Second Floor
1 1/2" = 1'-0"
2x6 WALL STUD
NAILING FOR SHTG
7/16" OSB SHTG
FOUNDATION
PAB4-12 ANCHOR BOLTS*
* STHD14 HOLD-DOWNS AT SHEAR WALL ENDS
Foundation
1 1/2" = 1'-0"
AUTODESK
ASCE
BYU Timber Strong
Details
Project Number 001
Date 2/3/2023
Drawn By Steven Okelberry
Checked By Emma Kratz, Nathan Porter
104
Scale 1 1/2" = 1'-0"

Main View Scale:



Color Key:

Dimension Lengths
Beam Type

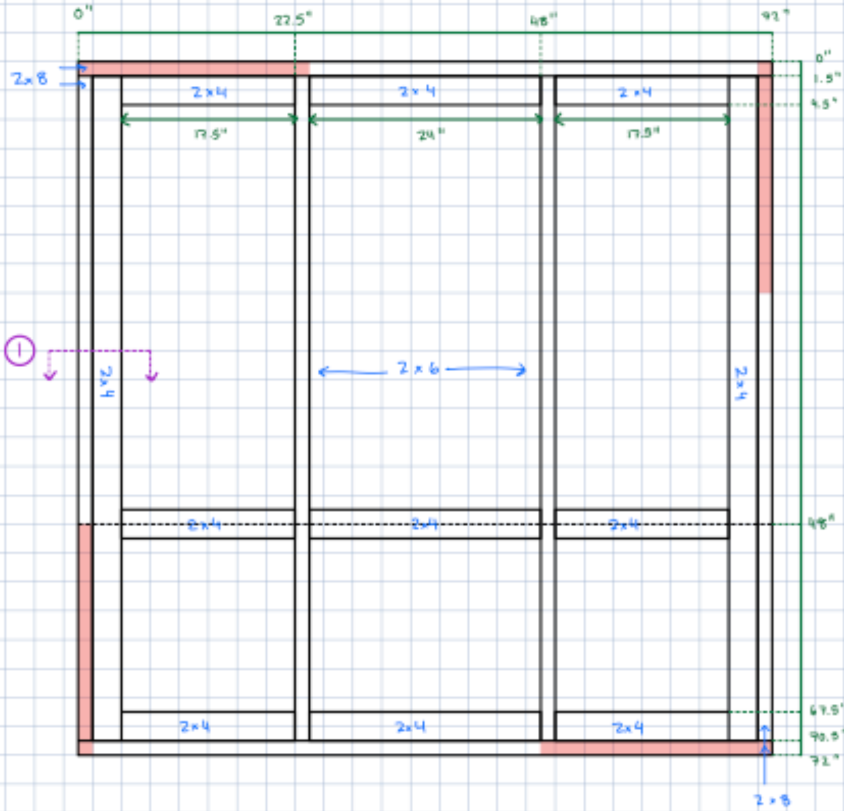
How Dimensions will be listed:
(# of this size member): (dimension" x dimension" x length')
Note: measurements are approximate, make sure to measure and check the actual structure before cutting.

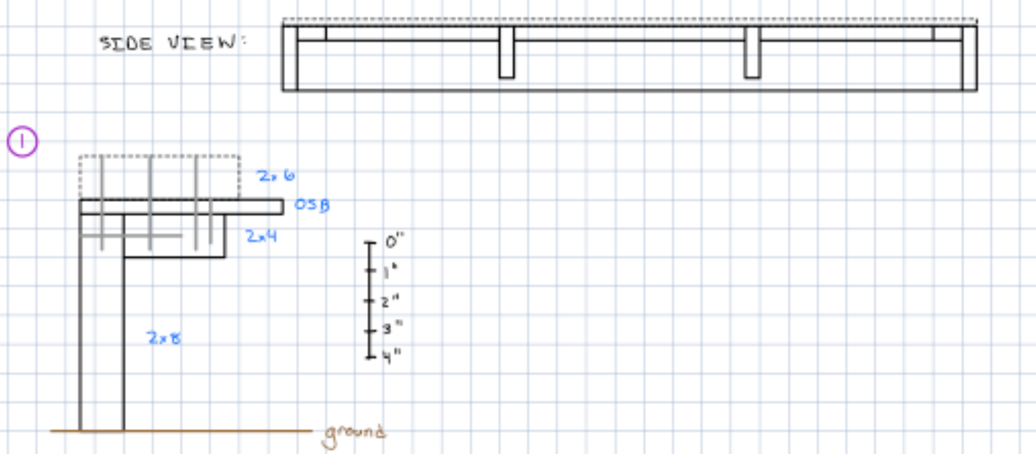
2x4 is 1.5" x 3.5"" (2 nails)
2x6 is 1.5" 5.5"" (3 nails)
2x8 is 1.5" x 7.25" (3 nails)

Nathan Porter

1st Floor Cut List:

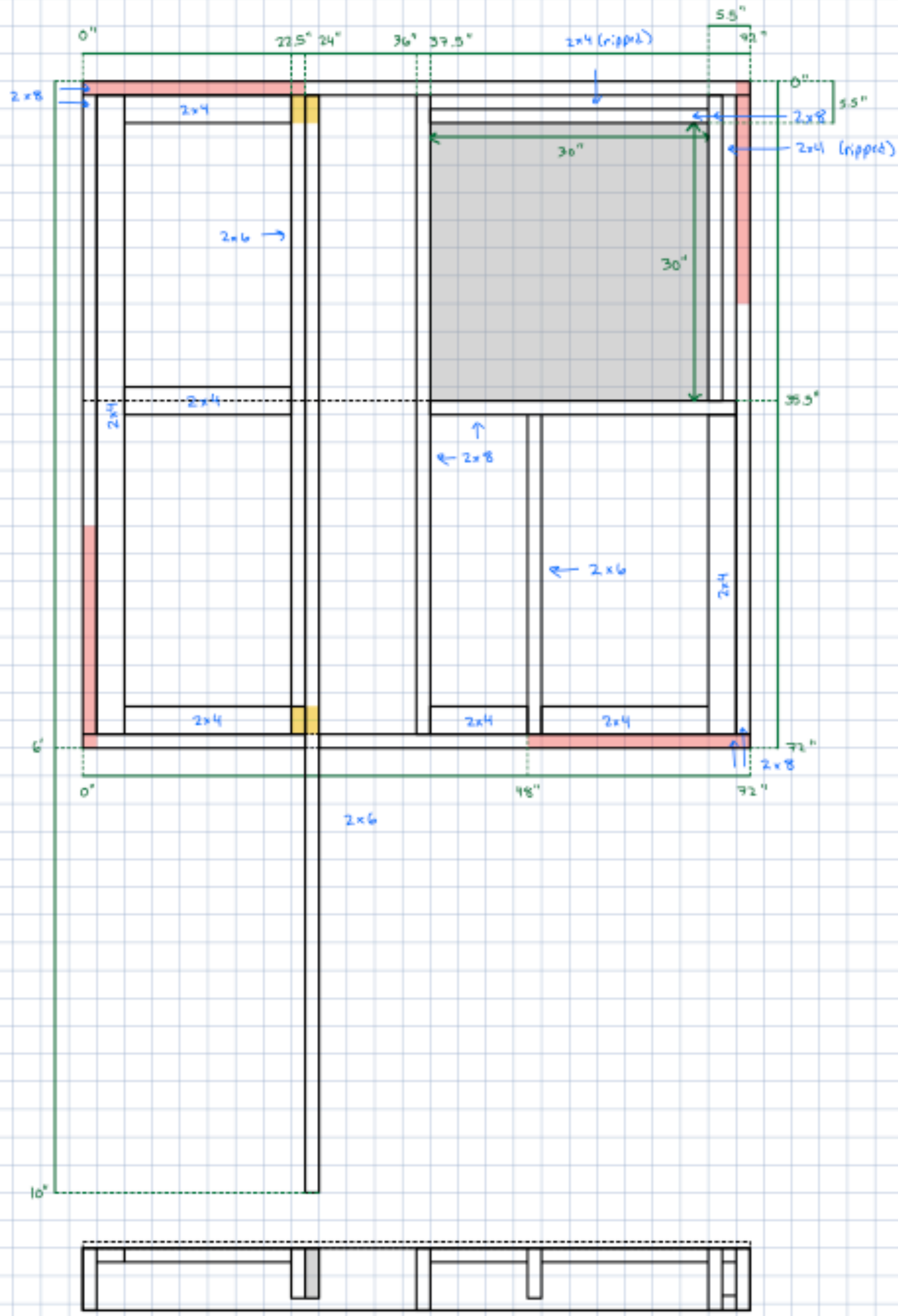
- 2: 2" x 8" x 72"
- 2: 2" x 8" x 69"
- 2: 2" x 6" x 69"
- 2: 2" x 4" x 69"
- 6: 2" x 4" x 17.5"
- 3: 2" x 4" x 24"
- 1: 2' x 6' OSB
- 1: 4' x 6' OSB





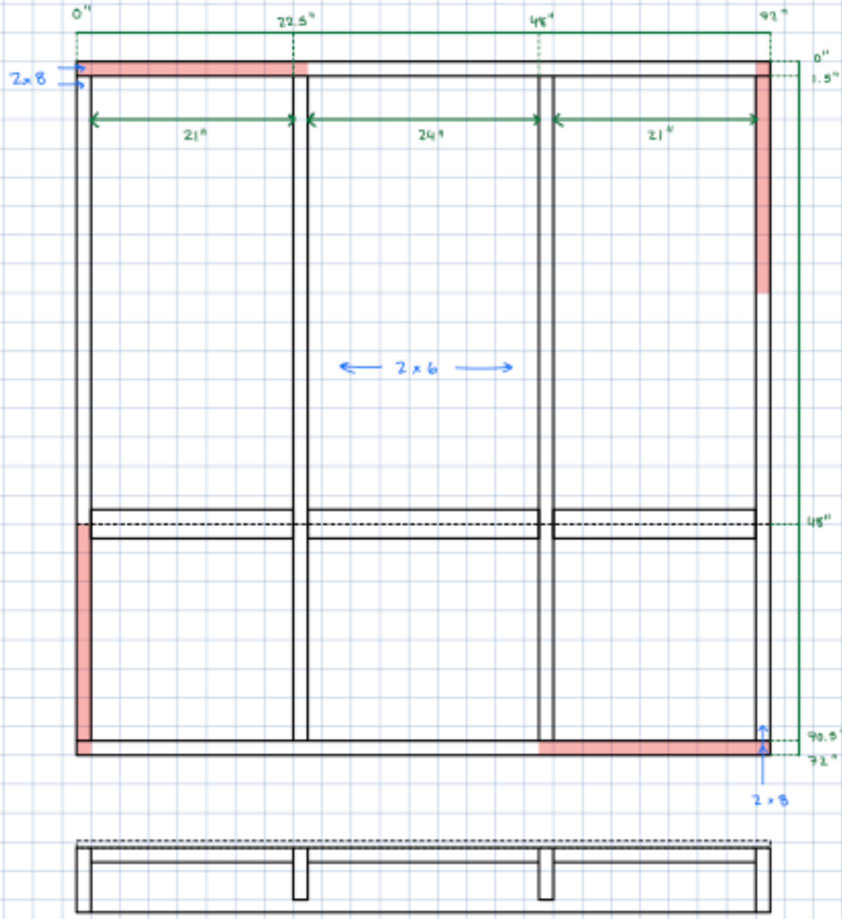
2nd Floor Cut List:

- 2: 2" x 8" x 72"
- 3: 2" x 8" x 69"
- 2: 2" x 8" x 34"
- 1: 2" x 8" x 30"
- 1: 2" x 6" x 69"
- 1: 2" x 6" x 33.5"
- 1: 2" x 6" x 9'10.5"
- 1: 2" x 4" x 5'9"
- 1: 2" x 4" x 33.5"
- 1: 2" x 4" x 10.5"
- 4: 2" x 4" x 17.5"
- 1: 36.5" x 6' OSB
- 1: 35.5" x 6' OSB

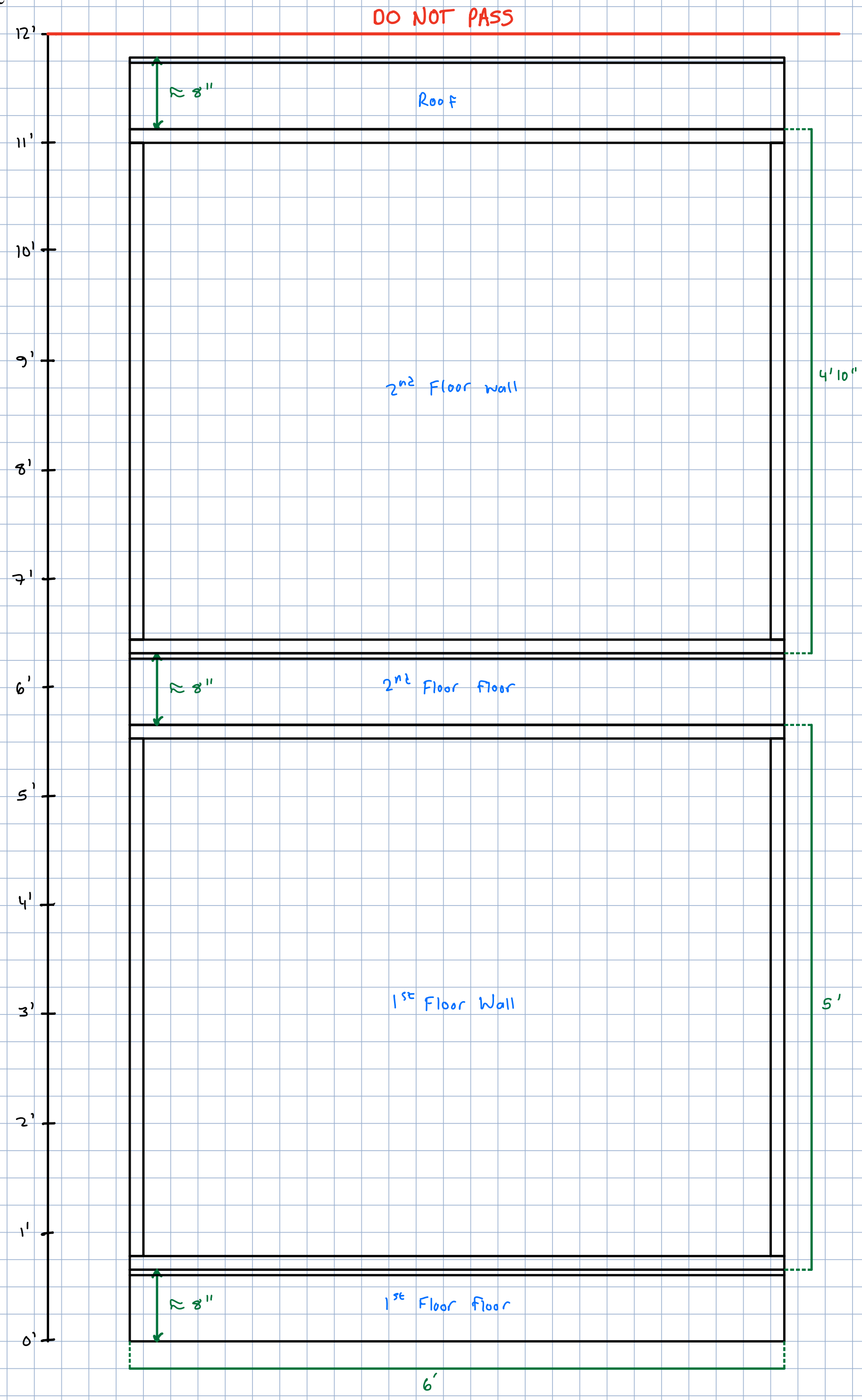


Roof Cut List:

- 2: 2" x 8" x 6'
- 2: 2" x 8" x 5'9"
- 2: 2" x 6" x 5'9"
- 2: 2" x 4" x 21"
- 1: 2" x 4" x 24"
- 1: 2' x 6' OSB
- 1: 4' x 6' OSB



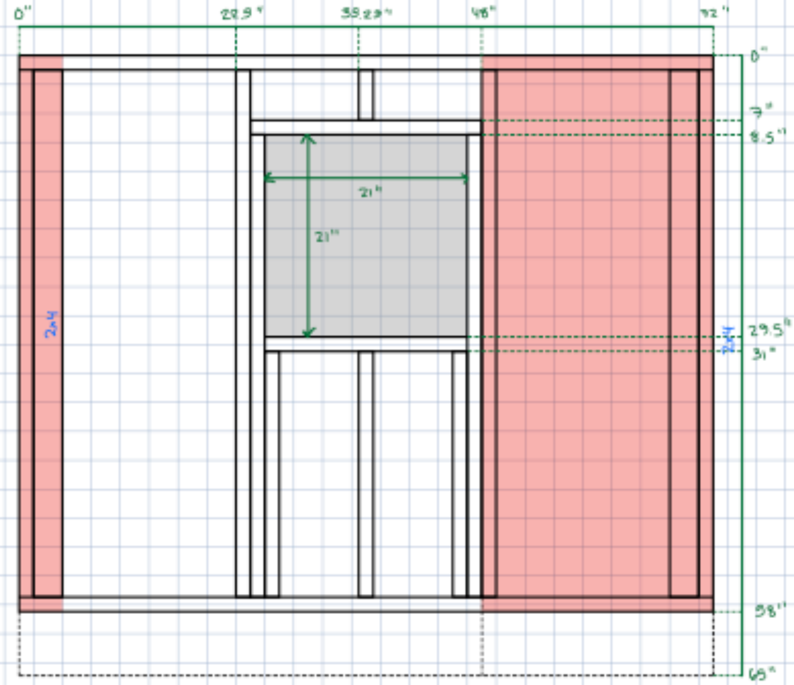
Basic Wall Profile



South Wall Cut List:

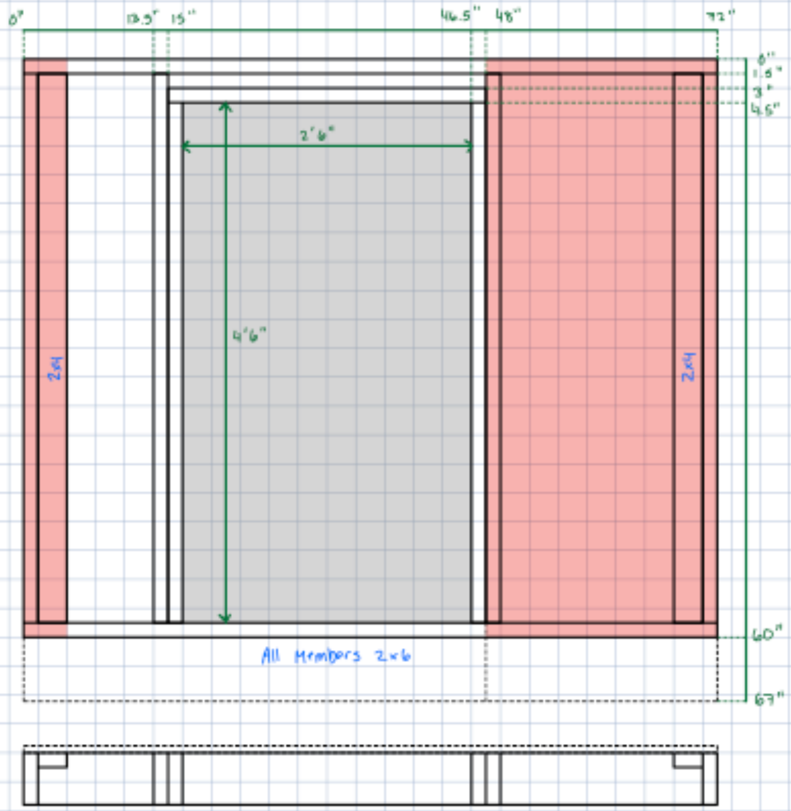
2nd Story:

- 2: 2” x 6” x 72”
- 4: 2” x 6” x 55”
- 2: 2” x 6” x 48”
- 3: 2” x 6” x 25.5”
- 1: 2” x 6” x 5.5”
- 1: 2” x 6” x 24”
- 1: 2” x 6” x 21”
- 2: 2” x 4” x 55”
- 1: 48” x 65” OSB
- 1: 24” x 65” OSB



1st Story:

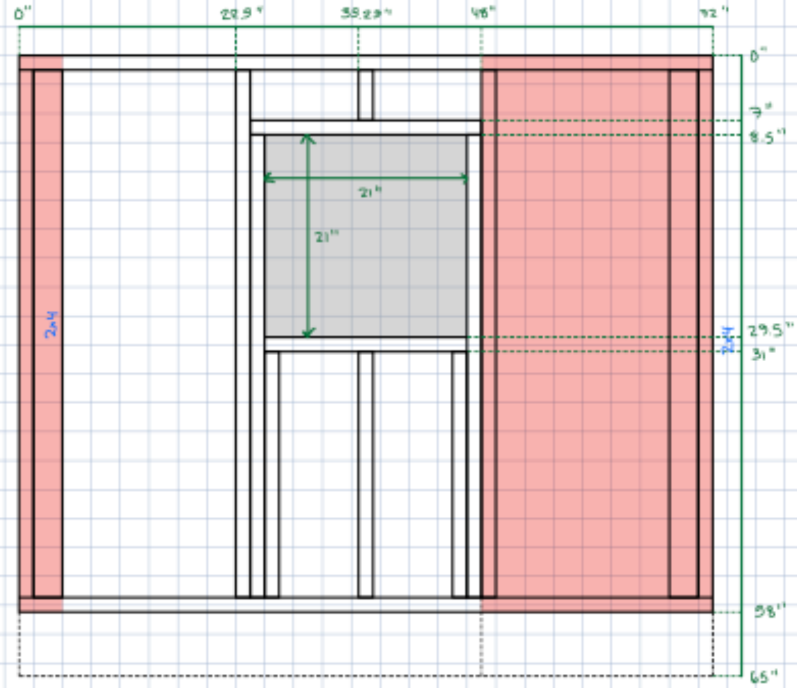
- 2: 2” x 6” x 72”
- 4: 2” x 6” x 57”
- 2: 2” x 6” x 54”
- 2: 2” x 6” x 33”
- 2: 2” x 4” x 57”
- 1: 48” x 67” OSB
- 1: 24” x 67” OSB



North Wall Cut List:

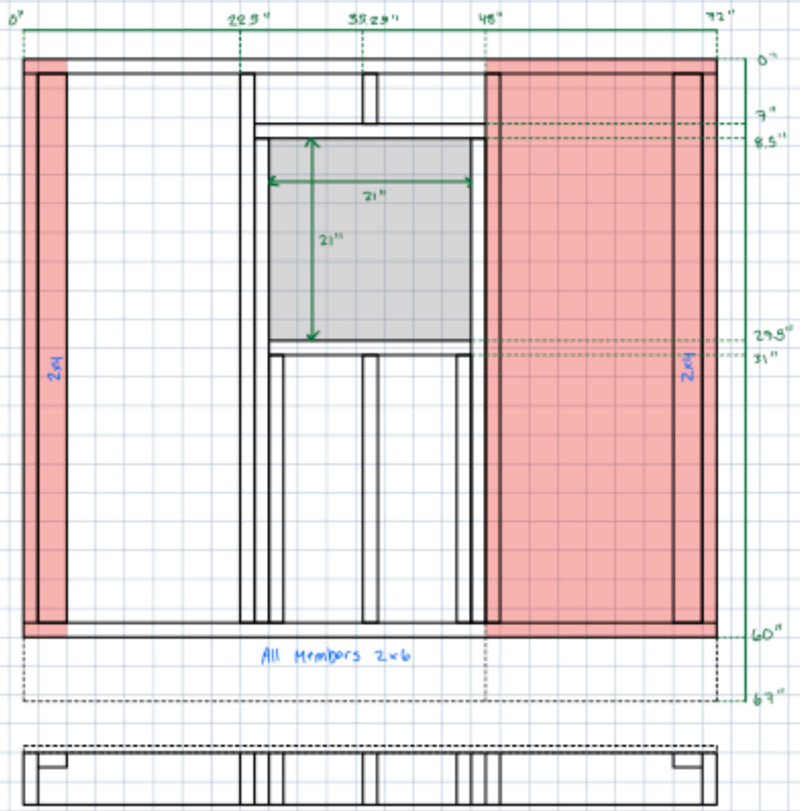
2nd Story:

- 2: 2” x 6” x 72”
- 4: 2” x 6” x 55”
- 2: 2” x 6” x 48”
- 3: 2” x 6” x 25.5”
- 1: 2” x 6” x 5.5”
- 1: 2” x 6” x 24”
- 1: 2” x 6” x 21”
- 2: 2” x 4” x 55”
- 2: 2” x 4” x 55”
- 1: 48” x 65” OSB
- 1: 24” x 65” OSB



1st Story:

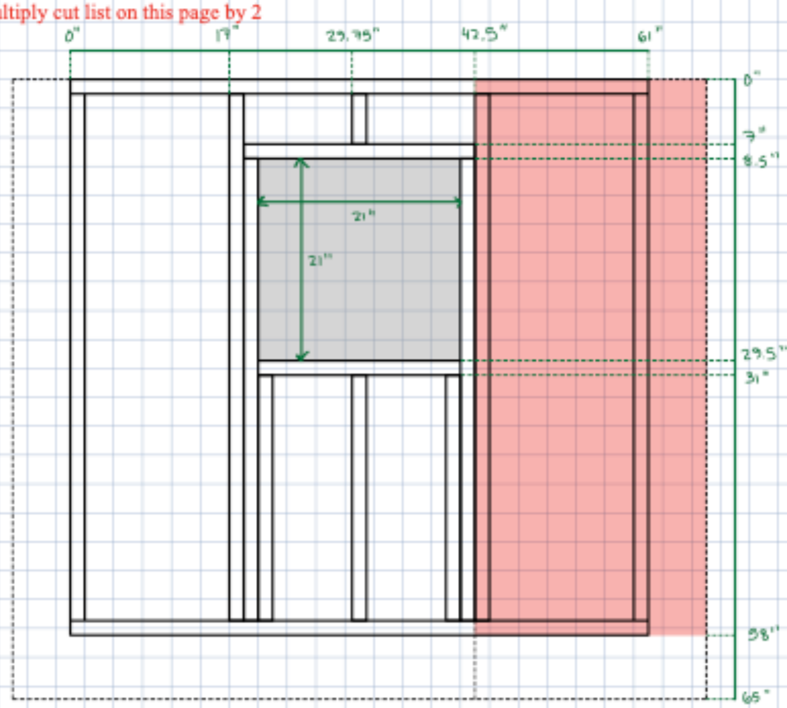
- 2: 2” x 6” x 72”
- 4: 2” x 6” x 57”
- 2: 2” x 6” x 48”
- 3: 2” x 6” x 27.5”
- 1: 2” x 6” x 5.5”
- 1: 2” x 6” x 24”
- 1: 2” x 6” x 21”
- 2: 2” x 4” x 57”
- 2: 2” x 4” x 55”
- 1: 48” x 67” OSB
- 1: 24” x 67” OSB



East and West Wall Cut List: multiply cut list on this page by 2

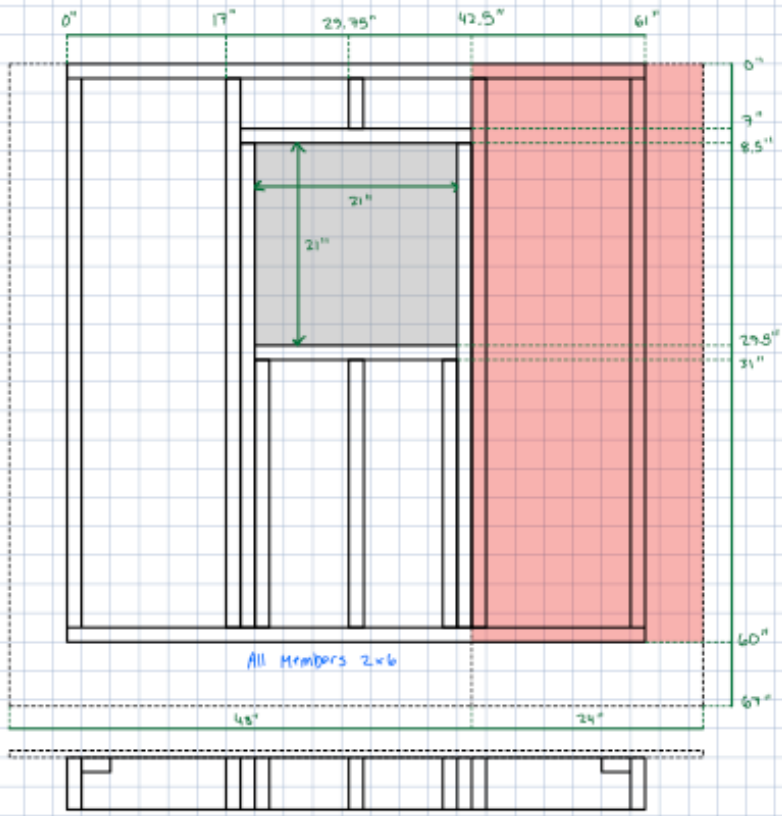
2nd Story:

- 2: 2” x 6” x 61”
- 4: 2” x 6” x 55”
- 2: 2” x 6” x 48”
- 3: 2” x 6” x 25.5”
- 1: 2” x 6” x 5.5”
- 1: 2” x 6” x 24”
- 1: 2” x 6” x 21”
- 1: 48” x 65” OSB
- 1: 24” x 65” OSB



1st Story:

- 2: 2” x 6” x 5’1”
- 4: 2” x 6” x 4’9”
- 2: 2” x 6” x 48”
- 3: 2” x 6” x 27.5”
- 1: 2” x 6” x 5.5”
- 1: 2” x 6” x 24”
- 1: 2” x 6” x 21”
- 1: 48” x 67” OSB
- 1: 24” x 67” OSB



Appendix E: Phase 4 Visual Aid

BYU ENGINEERING
Civil & Construction Engineering

CAPSTONE

CCE-CPST-0 06

Timber-Strong Design Build Competition

Team members: Emma Kratz-Bailey, Steven Okelberry, Nathan Porter

April 11, 2023

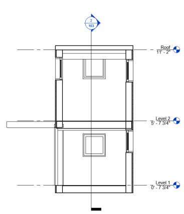
Motivation and Concept

The Timber-Strong Design Build competition is one wherein a team of undergraduate students design every phase of a sustainable, 2-story wood light-framed building. The competition was started to encourage students to learn to work in teams, and to teach them about the phases of building, but also to get them familiar with wood as a building material. In the competition rules document, it is stated that “while other natural resources are rapidly depleting, wood is the only building material that grows naturally, is 100% renewable, and outperforms other building materials in overall carbon footprint reduction.” Thus, the competition encourages students to design "an artistically creative building that is sustainable, aesthetically pleasing and structurally durable.” Additionally, in the interest of sustainability, after the Intermountain Southwest Symposium the project is to be disassembled and donated for repurposing.

The concept for our building draws from BYU’s long, proud history of sobriety. BYU has ranked #1 on the Princeton Review’s “Stone Cold Sober” and/or “Cancel the Keg” category for 24 years running. The university often celebrates the achievement with specially labeled bottles of the famous BYU Creamery chocolate milk. BYU is also well-known for a love of nerd culture, including such things as Dungeons and Dragons and Lord of the Rings. Given that our structure was required to feature a cantilever beam, the likes of which a tavern sign might hang from in days of old, we thought a fun twist on our design would be to construct a mini “chocolate milk tavern,” with inspiration for the name taken from The Lord of the Rings books.

Design Features

The design of the structure mirrors the requirements given in the rules as far as dimensions and basic layout go. In meeting these requirements and providing adequate strength for the specified loads, we employed **primarily 2x6 and 2x8 members**. 2x8 members are used as perimeter members for the floors and roof, while 2x6 members comprise the studs and vertical members. 2x4 members were added in convenient locations for the sake of framing convenience.



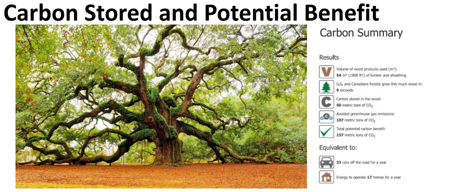
The floors and roof all have the same design for the sake of simplicity. Windows and doors are placed in such a way as to facilitate easier framing, and to allow our shear walls to meet the aspect ratio required by American Wood Council Special Design Provisions for Wind and Seismic. Additionally, we used a **flat-roof** approach for the sake of our creative design, and ease of modeling and construction.

Factors of Safety

The **diaphragm** of our structure is comprised of unblocked 7/16” OSB sheathing with 8d nails at 6” on-center, with floor and roof joists spaced at 24” on-center. With the 2x8 perimeter members specified, this provides a Factor of Safety of **1.77**. It is worth noting that 5/16” OSB sheathing would be adequate, but due to material availability 7/16” OSB sheathing was used instead.

The **shear walls** also use 7/16” OSB structural 1 sheathing panels with 8d nails at 6” on-center. The segmented shear wall approach was employed. STHD14 hold-downs are used at the foundations, with LSTA18 hold-downs at the second level. ½” diameter PAB4-12 anchor bolts spaced at 6” on-center are used for the shear walls. This shear wall plan has a Factor of Safety of **2.19**.

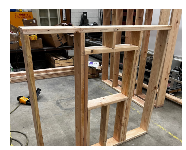
Carbon Stored and Potential Benefit



With our framing volume multiplied by 100 in order to simulate the construction of a full-sized building, we have a total of **50 metric tons of CO2 stored** in our structure, as calculated using WoodWorks’ carbon footprint calculator. However, for a full-sized building using this framing plan, we would also reap a potential carbon benefit of 157 metric tons of CO2. That’s enough to power 17 homes for a year, or the equivalent of taking 33 cars off the road for a year!

Material Cost

The total material cost of this structure is estimated to be **$2,354.76**. As the building was constructed by students, there was no labor cost, but the labor cost would likely be comparable to an average wood-frame building if the plan was produced on a normal scale. This is expected, as there are no overly novel construction or framing methods employed in the construction of this building.



Structure Weight

The total material weight of our structure is calculated to be **1189.99 pounds**, or 1.2 kips.

Our Sponsors

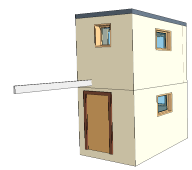
We would like to fervently thank the American Society of Civil Engineers, American Wood Council, Simpson Strong-Tie Company Incorporated, and APA—The Engineered Wood Association for providing us with the opportunity to learn more about wood design, construction, and sustainability alike.

AMERICAN WOOD COUNCIL APA ASCE SIMPSON Strong-Tie

Wrapping Up

After construction and dismantling, the structure will be donated to Orem, Utah’s Habitat for Humanity’s **“Habitat ReStore”** program, which accepts wood building materials and resells them at a low cost. We will thus use decorative butcher paper decoration to bring our vision to life, as painted wood is not accepted by Habitat for Humanity. Thus, after construction, these materials will be kept out of landfills, and be given the opportunity for **“second life”** through resale.

Habitat for Humanity® ReStore



The Team

Our team included several underclassmen, in addition to the members working on the project as part of their senior Capstone experience. All of these team members are part of the BYU ASCE Student Chapter. The full team roster is as follows:

Emma Kratz-Bailey, secondary team captain
Senior in civil and construction engineering
Structural and seismic resistance emphasis
Avid D&D player

Ava Pfeil, builder
Freshman in civil and construction engineering
Renewables and commercial construction emphasis
Loves reading, especially “The Great Alone” by Kristin Hannah

Nathan Porter, build team captain
Senior in civil and construction engineering
Structural emphasis
Framed a house in high school

Steven Okelberry, builder
Senior in civil and construction engineering
Hydrology and heavy civil construction emphasis
Manages the surveying for civil and utility installation For a $1B data center

Savannah Thomsen, builder
Sophomore in civil and construction engineering
Structural emphasis
Graduated high school in the same town as Napoleon Dynamite: Preston, Idaho