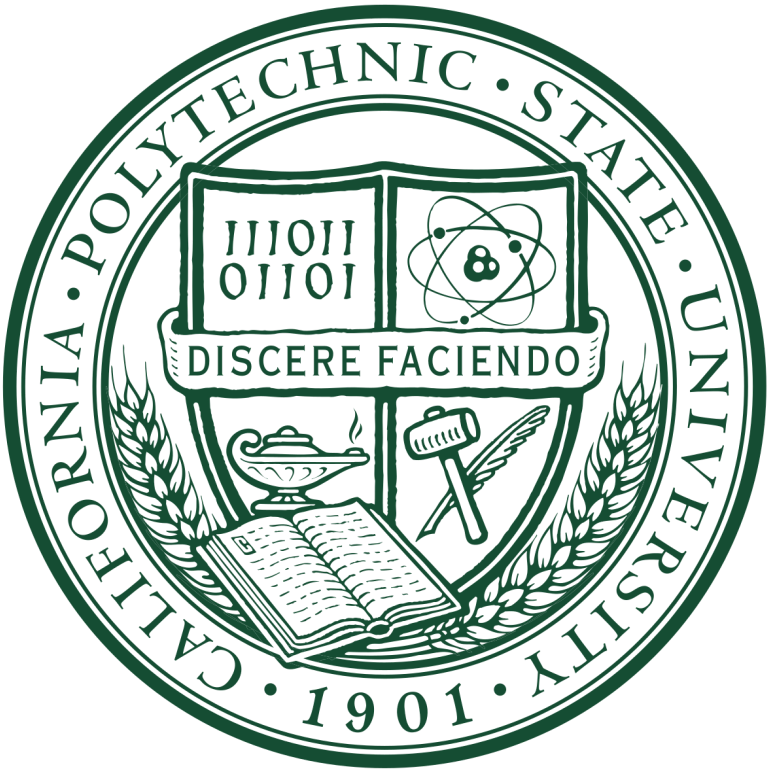
Timber-Strong Design Build ARCE Group
Senior Project Final Report



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Design Phase & Competition

The 2019 Timber-Strong Design Build Competition was developed by the American Wood Council, Simpson Strong-Tie Company Inc, and APA - The Engineered Wood Association to cultivate timber design, building, and sustainability experience for students. Participating students gained exposure to performance analysis, construction management, building practices, and project bid preparation while practicing as a design construction firm. In the process of this hands-on experience, students were expected to procure all building materials and tools themselves.

The Timber Strong senior project consisted of participating in the Timber-Strong competition, then re-purposing the structure for use as a playhouse in a pre-school. The intent of the project was to explore sustainability options after finishing the competition, allowing the students to experience hands-on construction, marketing, professional communication, and a realistic interdisciplinary process.

Planning and scheduling were the first part of the Timber Strong Competition. The project began two weeks before the final calculations were due, which allowed the team a small window to complete the design and submit the report which can be seen in appendix 1. An additional two weeks were given to fully prepare for the competition by cutting and assembling our structure prior to the competition. The Timber Strong competition included the design, calculation, cost-estimation, scheduling, and construction of a 4’ x 6’ wooden structure. The parameters included an 8’ height limit, a 135 lb point load applied on a 4’ cantilever, and 350 plf theoretical seismic lateral force applied in both directions.

In order to satisfy the competition requirements, the team utilized a few unique ideas to show their understanding of the project. The first idea was a tapered ridge beam. The competition called for a 4’ cantilevered ridge beam with a 135 lb point load as mentioned above. The deflection at the end of the ridge beam would be tested multiple times, and was required to be between 0.5” and 1.0”. Through the initial calculations, the team devised a 2x5 ridge beam tapered into a 2x4 at the end would best satisfy the deflection requirements. The second unique idea was the utilization of OSB in areas that did not require structural plywood. They did this to show their understanding of where exactly structural plywood was necessary, and where they could use a cheaper and more efficient material.

A parameter in the project competition was to find the total CO2 footprint our structure is creating. This part of the project tied in an important theme of the competition of sustainability and the environmental impacts of building construction as a whole. In an ever changing world, this is an important category to take into consideration. The carbon footprint

of our building come from many different factors including the chopping of trees, manufacturing and transportation pollution, and unused material waste. We focused on optimizing our design to reduce the carbon footprint as much as possible. Optimizing the design was done by using maximum spacing of members yet keeping member sizes to a realistic level, and other similar design considerations.

The second part of the Timber Strong competition was the construction process. The team was allowed to prefabricate the individual cuts for each piece, as well as build all the stud walls before the competition. They were then given one and a half hours to complete the entire construction process. This included putting the stud walls together, fabricating the roof, and nailing on all the sheathing around the entire building.

Overall, the Timber Strong competition was an eye opening experience in the construction process, however there are a few changes to the competition that would greatly benefit the immersive experience. A recurring problem found in the project prompt was ambiguity in what was expected in many portions of the calculations and construction process. For example, designing to code for a 4'x6' structure was unrealistic, as using a 20 psf live load for the roof resulted in a heavily over-designed roof system. In addition, the project prompt never specified whether or not to use ASCE 7-16 load combinations for lateral loading, it only stated to design for a 350 plf lateral load. Also, it was permitted to have the walls minus the sheathing fully prefabricated, but it never stated specifically what can be considered wall components. This left ambiguity in the requirements for prefabrication of double top plates and top plate/rafter connection hardware. These are just a few of the equivocal requirements found in the Timber Strong competition guidelines that could have used more detailing.

Figure 1: Entire group (except Max) at the Timber-Strong Competition, post-construction

One of the possible processes that we could have done differently would have been testing the Modulus of Elasticity of the ridge beam prior to calculations and construction. One component to the competition was how closely a team could come to estimating the deflection of their respective ridge beam cantilevers. Knowing the actual E_{min} of the wood being used for the competition rather than estimating the modulus given in the NDS 2015 would have produced a much more accurate estimate of the deflection.

The biggest obstacle faced for this competition was the time crunch the team was burdened by. While other teams had a full year to prepare and learn from previous mistakes made in last year's competition, this project was issued to the team only two weeks before the competitions due date. The two weeks the team was given to do all of the calculations, drawings, and other related report material was an insufficient amount of time, as the team also had design labs and other classes at the same time. To make things worse, they only had two more weeks after that due date to practice and prefabricate the structure. Two weeks may have been enough time to fully prepare, but the first week we had was during our spring break. This gave the team only one realistic week to practice and prepare for the competition.

During the competition, there were times where the team struggled with organization and sticking to the game plan. The final time it took our team to complete the building was around 1 hour and 24 minutes. Compared to the allotted building time of 1 hour and 30 minutes, the team did not have a speedy time. In hindsight, it would have been beneficial to get in more practice before the competition. Having more practice sessions where the team is timed and using the same conditions the competition mandated would have made for a quicker build time and an overall better construction of the structure.

Another aspect of the competition that wasn't taken into much consideration was architectural finishes of the overall structure. As the competition proceeded, it was observed that most teams had some sort of architectural/aesthetic finishes on the structures such as asphalt roof tiles, turf roof finish, door frames, siding, and other interesting finishes. This would've been an easy and beneficial addition to the structure, as that portion was a heavy portion of the overall score.

After the competition, we had further plans to repurpose the structure into something utilizable and functional. Our purpose since the start of the project was to make something that could be further used to become more than just a mere project and competition. Our goal for after the competition was to make the structure cost effective for building yet efficient, and something that would be useful for the means of society.

One main problem that we ran into which really set us back was finding a client. We thought it would be easy to just give the structure away to someone, but it turned out to be a lot harder than we thought. This was a great learning lesson for us to not take things for

granted, and to really have to pitch ourselves to clients to make a compelling case for ourselves. Though we really wanted to donate to a preschool to be a playhouse for kids, ultimately there was too much confusion in terms of licensing for the structure due to county laws, and too many complications in the way that it was designed for that goal to have been possible. Factoring in cost, time, design, aesthetics, etc., we decided on making a dog house. We liked the idea because we knew a dog house would be more appealing to more clients because it gave us a broader target market, and because the cost of making a dog house would be significantly less (as we are all college students). We also really liked the idea of making something helpful for the community, and though it is of lesser extent than a playhouse, we were satisfied with our purpose for the project.

The time crunch played a large role in our building for the competition, but with the extra time we had during Spring Quarter, we were able to work carefully and diligently in bringing a much more pleasing finished product. After carefully going over plan drawings, details, materials, and specifications of the project, we began building the dog house.

Figure 2: Aerial View of the team working on the structure at the Timber-Strong Competition

Post-Competition Phase

This structure was made by building off of the remaining pieces of the project used for the Timber Strong Project, as well as adding in waterproofing, exterior pieces, reinforcement,

and many other things. Using most of the same calculations and timber pieces, we kept the same plan dimensions of the 4’ x 6’ structure. One major change was changing the height of the building from 6’ (to the top of the top plates) to 4’. This allowed us to take out unnecessary wood and equipment needed in those areas, reducing the cost and weight of the structure. In addition, it allowed a much more aesthetically pleasing structure and a more proportional view.

Our building process started with deconstruction of the building to fix all the building errors and mistakes that we made, such as missed nails, un-flush edges, non fitting pieces, etc. By deconstructing, it gave us an idea of all the things we did wrong, which definitely helped us in the long run. By starting over instead of just trying to fix old mistakes, we learned a lot more in the process of building and how scheduling and ordering of the fixture of pieces matters so much. The competition allowed us to be more effective and efficient with our time, and taught us to be more precise with our drawings and details. By taking our time laying out and reviewing the plan drawings and details week after week, as well as using our experience from the competition, our building became much more smooth and efficient.

We cut the studs to shorter lengths to accommodate our changes made in the elevations and plans, and from there we polished up all our past mistakes and fabrication errors as stated earlier (missed nails, un-flush edges, non fitting pieces).

One thing we really focused on for the post-competition was the repurposing of the structure. We had a vision of making the building look nice on the outside, as well as functional for weather conditions. With this in mind, we added a 4’ x 6’ floor using pressure treated wood to withstand weather conditions that regular timber materials could not. Adding the flooring also helped us keep the structure balanced and more secure when building the walls and roof, which became very important later on. In addition to the floor, we wanted to make our project suitable for all types of weather. We attached waterproofing, flashing, shingles, roof tiles, and much more to help with the integrity of the building, and based our designs off of how typical houses are made in California. We followed the process for how buildings were made and in which order that materials were places, and this really helped us in learning more about how the sequence of events in construction matters so much to the finishing of a building.

As stated earlier, for the competition we didn’t incorporate many architectural finishes. With this in mind, we wanted to make our structure look nicer and more pleasing. We added wall siding and roof shingles to make our exterior look as if it were a miniature house, and we really enjoyed the look because it was simple yet pleasing.

The culmination of this project from it’s early design ideas into a fully finished waterproofed structure showed us the true importance of constructability, often an uncommon topic in structural engineering. We will incorporate easily assembled designs in our future

endeavors and careers as future engineers; as this project truly conveyed to us the problems construction managers face all the time.

Figure 3: The client (Vince) with the finished dog house

Global Impact

The Timber-Strong competition was a huge competition with over 20 schools from across the western United States participating. By exposing so many students to various aspects of timber construction, it can have a global impact on the structural engineering community. Also, the collaboration of these students and schools with the Pacific Southwest Conference and Simpson Strong-Tie will make the industry more interconnected and help build long lasting relationships.

Societal Impact

From the very beginning of this project, we knew we wanted to repurpose our final structure into something that would benefit the San Luis Obispo community. In the end, we decided to convert our final structure into a dog house. The recipient of our dog house is Vince, who is a member of the CAED shop here at Cal Poly. By donating our dog house to someone who needed it, we were able to give back to the San Luis Obispo community as well as the

community on campus. It felt great to help Vince out as he has helped us so many times during our 4 years here, whether it was in the fabrication shop or in the Concrete High Bay lab.

Cultural Impact

The Timber Strong Competition creates its own type of culture on Cal Poly's campus. With all the different schools and competitive energy in the air, it makes for a fun weekend. We hope that by competing in this competition and representing Cal Poly for the first time, we will help create a long-lasting culture of competitiveness here at school and that teams will compete and represent our school in many competitions to come.

Environmental Impact

Building design has recently shifted towards designing "green buildings," or buildings that are energy efficient and uses sustainable resources. Timber is the most renewable and sustainable resource, so being able to participate in a competition that revolves around using timber was valuable. For the competition, we also had to consider and compute our carbon footprint effect, and consider how we can design a structure that is efficient with resources. Timber is also a resource that can be sourced locally, so reducing transportation costs reduces our carbon footprint. With the TImberStrong competition as well as finishing this senior project, we were able to practice designing with timber, as well as constructing it to minimize waste and maximize efficiency.

Economic Impact

Being able to design and construct with timber is economically the best choice. Timber construction costs are lowest, compared to steel, concrete and masonry. Timber is also the cheapest and most sustainable construction resource. Also, building a timber structure along with Incorporating Simpson Strong-Tie connections allowed us to save time during the construction process. This senior project taught us the importance of scheduling and time management during construction, and that saving time saves money. We also learned how expensive architectural finishes can be. From this, we learned that we have the challenge or opportunity in our careers to exhibit structure in a way that is architecturally pleasing so that we can reduce architectural costs.

Constructability Impact

The TimberStrong competition taught us the impact we have as engineers on those in the construction field. Having to construct a structure that we designed, and having to do so in a short window of time, exposed to us the importance of having construction considerations when designing. Being able to simplify construction and reduce its costs through the design process is a valuable lesson. It taught us the importance of producing thorough and organized construction plans. This competition also taught us that there are better ways to construct, such as avoiding construction at high elevations, or managing construction areas when having to build in a confined space. This experience of handling the construction first hand really taught us the importance of our duty as engineers to create construction-friendly plans.

Personal Reflections

The most difficult part of the project to learn on our own were the architectural finishes and how to apply them correctly. As an ARCE student, we don't learn much of the architectural side of things. Installing the flashing and waterproofing proved to be rather difficult even with the various research we as a team had done. Our sources did not demonstrate the process in any real clarity, I found that actually installing the waterproofing and understanding the process first-hand to be much more beneficial. Understanding the logic that goes behind the layers and how to properly lap them over each other to make a working waterproofing. CJ

During the course of this project I grew as a person and as an engineer in ways I would not have expected before beginning the project. From the very beginning I realized that our team would encounter various issues due to the nature of our project, but some unexpected issues arose that tested my work ethic, patience, and teamwork. At first, we were given the task to design and partially construct a building in a little less than a month. While we managed to complete the design, we had issues with work completion and proper detailing that caused issues throughout the rest of the competition. This issue propagated throughout the rest of the project and eventually tested the limits of my patience and teamwork as I dealt with unruly group members. This testing of my teamwork capabilities showed me a cruel and realistic view of the real working world, and I value this experience greatly because of it. I believe that when I enter the workforce this experience will greatly improve my relations with my peers and coworkers, thus allowing me to avoid unfortunate situations due to miscommunications or misunderstandings. When it comes to physical learning aspects, I learned how to properly plan for construction, and the hardships that come around improper scheduling and constructability

order. I also learned the proper way to include waterproofing in the architectural skin of a building. Before this project, I had no idea how to apply waterproofing or keep the entire skin watertight. Actually putting the waterproofing paper on, as well as the flashing and shingles allowed me to gain a greater understanding of the process and its limitations. Overall, I learned a great deal about communication with team members, as well as real world construction problem solving. NW

The TimberStrong Senior project covered many different facets of what the Architectural Engineering curriculum is lacking at Cal Poly. The process of architecturally finishing a structure was heavily underestimated by the whole group, but was soon taken seriously after realizing the difficulties construction managers go through every day. I will venture into the engineering industry with constructability constantly affecting my design choices, as an evenly constructed building is a better building structurally wise. The difficulties of working in such a large group for a project like this was a huge learning process for me, as there were many logistical and communicational obstacles to overcome as a group. This group and project gave me so much value and knowledge to enter into the engineering and construction industry smoothly, and I am very thankful for the opportunity to cap off my learning experience with a project like this one. -RO

This senior project has been very eye opening to the construction process and consideration for construction during the engineering design process. The TimberStrong competition revealed to us the importance of having thorough and well organized structural drawings and the importance of structural details. This was emphasized from having to build in a short window of time. Having exceptionally correct and organized drawings would reduce the construction time and ultimately costs. Performing the construction process really taught me the importance of considering construction when designing as a structural engineer. For example, using a 3 x 15 timber beam, although structurally correct, is impossible to find at Home Depot and can only be acquired through a custom order through a lumber processor. Thus, it is more logical to use a 4 x 12, which is much easier to find and thus saves time and money. Learning the importance of construction considerations was the most important lesson from this experience. In addition, the process of finding a client taught me the importance of establishing good relations and communications with the client who influences architecture. Finding a client was difficult and put off the architectural design process and thus delayed the project. -CM

This project taught me a lot about the actual construction process of a timber structure. I knew from lectures the general idea, but actually going through and building the doghouse from the ground up made me look at the whole thing differently. We had to learn the various steps of construction and how to translate from concept to drawing to finished product. Increasing my knowledge of architectural finishes and their installation in particular was a huge part of this project. Before the completion of the doghouse, I had no idea how to waterproof, add flashing, or install shingles. However, now I feel confident that I would be able to do those things on my own. Another thing I learned during this senior project was how to communicate effectively in a large group. Our senior project team has 7 members and so finding time when everyone could meet and collaborate was a challenge. We worked around each other's schedules and were able to split up the work evenly. If one person couldn't come in to work, the other members would pick up the slack to ensure everything was completed on time. - MC

Throughout this whole project, there were a lot of unforeseen struggles and complications that affected the process of the building. One thing that stuck out to me was how complicated and complex that the construction process was. Being an ARCE student, we don't really see the construction part of things. With that in mind, it was very interesting seeing the whole project though and taking the necessary steps in a certain order to fulfill the goal. I think that learning how to schedule things, and how to make small goals for the day really propelled us to finishing this project on time. We started off with only a few weeks left to finish the project, but through scheduling and pacing, we were able to get it done. One of the most important aspects of this project was learning to be efficient with time, while still maintaining the integrity of the product. Through the method of the scheduling, I learned so much about the ordering of construction: from the finishes, to the waterproofing, and even the sheathing, etc. Sometimes I really had to think hard and do a lot of research about what job should be done first and how to know the right process for making a building into what it is. I think I learned how important efficiency is in this industry, and I gained valuable knowledge on how important accurate drawings are to create a structurally sound and aesthetically pleasing building. Through the process of trial and error of the Timber Strong Competition, we quickly realized how much the drawings are needed to make an accurate and efficient building. Good drawings led to good craftsmanship and proper structure. Through the project, I really gained knowledge on how architecture, structural engineering, and construction work together to create something so beautiful in a building. I learned so much from this senior project that I would never have learned on my own in term or working together in a group with fellow peers, and constructing a building to perfection. -NM