Son Care Foundation – Lean to Shade Structure Design and Construction

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This paper discusses the design and construction of a lean-to-shade structure built for the Son Care Foundation in San Luis Obispo. The Son Care Foundation is a nonprofit organization that raises guide dogs for veterans and first responders with PTSD. This shade structure is 16 feet long and 6 feet wide, its height slopes from 9 feet in the front down to 8 feet in the back creating a roof pitch of 2:12. The sheet metal roof also has an overhang of approximately 1 foot. As requested by the client, the shade structure was designed to fit the aesthetic of the existing shade structures in the area. After developing a design, with the assistance of architectural engineering students, structural calculations confirmed that the structure was designed adequately for all potential loading conditions. Due to the interdisciplinary collaboration required for the design and construction of this project, the Alliance provided funding for the project through their Hasslein Fund, which provides funding for projects that foster collaboration between different majors. The construction processes included in this project were site layout, excavation, concrete, framing, and roofing.

Key Words: Shade Structure, Shade Structure Design, Framing, Concrete, Roofing, Treated Lumber

Introduction

Cal Poly's Construction Management department was approached by The Son Care Foundation to ask students if they would like the opportunity to build a new shade structure in their dog agility training yard. They wanted this shade structure to be able to accommodate around 6 people at one time. The Son Care Foundation was unable to provide funding for the project. Team leader, Ryan McCann, collaborated with Gianna Rocca, an architectural engineering student, to create a design and corresponding load calculations. Construction plans, renderings, and a budget were then created and submitted to the Alliance for a funding proposal that was accepted. Construction was to start in early January of 2024 but due to significant rain fall the site was flooded. Even as weather conditions improved, the location of the proposed shade structure remained waterlogged due to poor draining conditions. Son Care Foundation executive Dillion Jamison made the decision that the shade structure location would move to the other side of the field where drainage was not an issue. Construction kicked off on April 11th, 2024 and was completed on May 11th, 2024. The majority of construction was completed by Ryan McCann and Julia Deegan, a Kinesiology major with an interest in occupational health and safety. Additional help was provided during the concrete pour from Business major, Andrew Higgins. Due to the activity of dog training classes on weekdays, construction only occurred Friday-Sunday.

Preconstruction

Preconstruction for this shade structure was split into two major activities, design and material procurement.

Design

Upon visiting the site and inspecting other shade structures a preliminary design was modeled off an existing structure. Once this design was submitted to the Alliance however, further inspection of the design deemed it to unapplicable for funding. With the help of Gianna Rocca, and other architectural engineering students, a new, much stronger design was created that still matched the aesthetic of the existing shade structures. This new design reflected the requirements of the structural calculations and local building code. A cost estimate was completed and a new funding request for the amount of $2,200 was accepted.

Procurement

Once funding was received material procurement began. All materials were procured from Home Depot, however multiple trips were need. A 12’ box truck was rented from Home Depot to deliver all larger materials. Separate trips to Home Depot were made for smaller items (hardware, fasteners, etc.). Materials were stored on site in the Son Care Foundation barn until they were needed, this was coordinated with maintenance staff to lock and unlock the barn as necessary. Due to multiple different types of Simpson Strong Tie connections used on the project, various different fasteners were needed. Table 1 depicts the final expenditures of the completed project.

Son Care Foundation Shade Structure					
Item	Quantity	Unit	Unit Price	Notes	Total Price
Hardware and Fastners					
SST #10x2.5" Hex Screw	1	Box	$ 21.00		$ 21.00
SST #10x1.5" Hex Screw	1	Box	$ 15.93		$ 15.93
SST #9x1.5" Hex Screw	3	Box	$ 13.94		$ 41.82
SST 1/4x3" Screws	1	Box	$ 12.74		$ 12.74
#10 1-1/2" Roofing Screws	2	Box	$ 9.98		$ 19.96
16Dx3-1/2" HDG Nails	1	Box	$ 19.98		$ 19.98
8"x1/2" Hot Galv Anchor Bolts	6	EA	$ 1.20		$ 7.20
1/2" Zinc Hex Nut	6	EA	$ 0.31		$ 1.86
4"x4" 12 GA Post Base	6	EA	$ 17.88		$ 107.28
4"x 18 GA Post Cap	4	EA	$ 6.21		$ 24.84
3"x3" Frame Anchor	20	EA	$ 3.48		$ 69.60
4"x 16 GA Post Cap Zmax	2	EA	$ 25.90		$ 51.80
1"x5" Tie Plate	4	EA	$ 1.12		$ 4.48
Tools, Equipment, Consumables					
Shovel	1	EA	$ 9.98		$ 9.98
Post Hole Digger	1	EA	$ 59.97		$ 59.97
Rubber Mallet	1	EA	$ 7.97		$ 7.97
Clamps 2Pk	1	EA	$ 27.97		$ 27.97
Caution Tape	1	EA	$ 6.97		$ 6.97
Mason Line (Orange)	1	EA	$ 6.30		$ 6.30
Mason Line (Pink)	1	EA	$ 12.97		$ 12.97
Metal Cutting Blade	1	EA	$ 27.97		$ 27.97
3/8" Concrete Drill Bit	1	EA	$ 11.97		$ 11.97
String Line Level	1	EA	$ 5.97		$ 5.97
Steel Square	1	EA	$ 6.47		$ 6.47
15" Handsaw	1	EA	$ 9.99		$ 9.99
48" Level	1	EA	$ 15.99		$ 15.99
Truck Rental	1	LS	$ 31.54	Used to deliver materials	$ 31.54
Safety Glasses	1	EA	$ 7.27		$ 7.27
Cut Level 1 Gloves	1	EA	$ 6.47		$ 6.47
6-1/2" Circular Saw	1	EA	$ 199.00		$ 199.00
6-1/2" Framing Blade	1	EA	$ 10.97		$ 10.97
1/4" Impact Driver	1	EA	$ 99.00		$ 99.00
Caulk Gun	1	EA	$ 4.98		$ 4.98
Lumber					
1x2x4 Stakes	2	EA	$ 2.76		$ 5.52
1x3x4 Stakes	4	EA	$ 2.96		$ 11.84
1.5"x18" Wood Stake	1	PKG	$ 6.58		$ 6.58
2x4x10 Treated Lumber	2	EA	$ 9.27		$ 18.54
2x4x8 Treated Lumber	8	EA	$ 7.04		$ 56.32
4x4x10 Treated Lumber	3	EA	$ 23.00		$ 69.00
4x4x8 Treated Lumber	3	EA	$ 16.44		$ 49.32
2x6x8 Treated Lumber	13	EA	$ 9.87		$ 128.31
4x6x8 Treated Lumber	4	EA	$ 30.27		$ 121.08
Roofing					
8' Corrugated 29 GA Steel Roofing	10	EA	$ 28.88		$ 288.80
Concrete Materials					
#3x12in Rebar	2	EA	$ 1.36		$ 2.72
#4x12in Rebar	12	EA	$ 2.32		$ 27.84
#4x36in Rebar	1	EA	$ 4.98	Mixing Concrete	$ 4.98
12"x48" Concrete Form Tube	3	EA	$ 27.99		$ 83.97
60# Quickcrete Concrete Mix	24	Bag	$ 3.67		$ 88.08
50# All Purpose Gravel	3	Bag	$ 5.37		$ 16.11
Misc					
Concrete Block	2	EA	$ 1.71		$ 3.42
Bag Fee	1	EA	$ 0.10		$ 0.10
Gorilla Construction Adhesive	1	EA	$ 11.98		$ 11.98
Quickcrete Construction Adhesive	1	EA	$ 8.98		$ 8.98
Subtotal (Before Tax)	$				1,971.70
Tax	8.75 %		$		172.52
Total	$				2,144.22

Table 1. Final Budget Expenditures

Construction

Construction for this shade structure was split into 5 major activities, layout, foundation work, framing, cross brace installation, and roofing.

Layout

For the layout of the project the site was first secured with caution tape with enough room to store materials and excavated dirt within the secured area. Layout began with setting up bater boards and finding the general footprint of the structure. A mason line was set, squared, and leveled and set to the desired dimensions. The mason line running off the batter boards met at each of the 6 corners of the soon to be 4”x4” posts. Using this guide line, we were able to mark the ground, with paint, using a template of our cylindric concrete formwork showing where to excavate and to what level. These string lines were used to pour concrete and set our post bases, after that, they were removed.

Foundation Work

The foundation for this shade structure consists of 6 12" diameter, 2ft deep footing piers. Each hole was dug to approximately 2ft deep but adjustments were made to account for the change in elevation from each hole to make sure the tops of each pier were level. Once each hole was dug, 12” Quickcrete cardboard concrete form tubes were set and leveled with dirt backfilled around them. At the bottom of each hole a 1inch thick layer of gravel was added to assist with drainage and to prevent concrete from being in direct contact with potential groundwater. Once form work and gravel were set Quickcrete concrete bags were mixed using a concrete mixer provided by the Son Care Foundation and poured into formwork. Two pieces of #4 rebar approximately 1ft long were added to each pier. Embedded in the piers were Simpson Strong Tie PBS ZMAX Post bases with an added 1/2"x6" anchor bolt for extra uplift strength. These post bases form the connection between the concrete piers and 4”x4” posts. Concrete was then left to cure for 7 days per the manufactures recommendation.

Framing

To begin framing 6 4"x4" lumber posts were cut to the correct length, (3 cut to 9ft and 3 cut to 8ft) and attached to each post base using SST structural screws. Once those were set, 4 8ft 4"x6" beams were set on top of the 4"x4" posts. At the ends the 4"x6" was fastened to the 4"x4" post with an SST Post Cap and structural screws. At the middle 4"x4" post where the two 4"x6" beams met, their ends were centered on the 4"x4" post and secured with an SST PC4Z Post cap and structural screws. After the 4"x6" beans were secured, roof rafter construction began. Rafters used were 2"x6"x8' with the ends cut at 10 degrees so they would all be flush. Accounting for approximately a 1ft overhang on each side, two birds mouth cuts were made on each rafter so it would sit flush on the 4"x6" beam. These cuts were marked using a speed square and the known roof pitch of 2:12 and then cut using a circular saw. These were then secured with 2 SST A33 angles and structural screws, on alternating sides on each end of the rafter. After the 9 rafters were set, 2ft on center, 2"x6" blocking was cut and secured using structural screws in the middle of the rafters running the whole length of the roof. This blocking alternated side to side between each rafter so they could be directly screw to the rafters. Lastly, cross braces were added from the 4"x4" posts to roof and 4"x6" beams to provide additional lateral support of the structure. The cross braces that attached to the 4”x6” beams were cut on each end at 45 degrees. The corner cross braces that attached to the angled rafters had to be held in place and marked and cut at custom angles.

Cross Braces

To provide extra foundation support, cross braces were added to the base of 5 of the posts and embedded in concrete 1ft deep, these were added for a couple of reasons. Fist was to support the moment of forces in the direction that the post bases provided no support for. These post bases only supported the 4"x4" columns in one direction, so without the cross braces, due to the moment force around the post base the structure would overtime begin to lean forward and eventually fall. Since the Son Care Foundation plans to move the existing fence to enclose the shade structure, these cross braces will not impede the function/use of the structure at all. Upon inspecting similar shade structures on site, many leaning forward and not having cross braces, our team could tell that these cross braces would be crucial to the longevity of our shade structure. Once secured and concrete had cured these embedded cross braces added great strength and stability to the structure.

Roofing

For the roof, 10, 8ft 29 Gauge galvanized corrugated steel sheets were used. These measured 25" wide and were lapped over the previously installed panel by 4 inches each time. These were then secured with 1.5" galvanized roofing screws with waterproof washers securing the metal to the rafters and blocking at a screw spacing of 6in. At some ends, the panels were not sitting flush together, to counter this issue, construction adhesive was added to secure the panels together and prevent issues with water leaking.

Lessons Learned

This project provided many lessons learned through the obstacles faced. One of the most significant issues this project faced from the start was ground water. Not only did it effect the location of the structure but it greatly effected the concrete cure quality of one of the piers. Groundwater had been accumulating in this hole when it was excavated but it was drained prior to concrete being poured. The concrete in this hole however never fully cured and remained moist for almost 3 weeks, this led to cracking and crumbly concrete when framing was installed on top. This made the post base bracket loose and wobbly, to counter this two 1” holes were drilled in the top of the pier, rebar was set in these holes and then a second layer of concrete was poured in a square form work on the existing pier to secure the post base to the concrete foundation. This fix ended up working but is unsightly to the trained eye.

The next issue encountered had to do with the rafter framing and roofing. When the sheet metal roofing was installed, ends of one panel to the next did not always sit flush. This was determined to be an issue with the rafters not being level. The rafters had become unlevel due to inconsistency with the bird’s mouth cuts. Since these were difficult cuts to make, they became significantly better with each rafter, causing the rafters level out towards one side of the structure which were the later rafters to be cut. Overall, the importance of having a level and square project from the earliest stages cannot be understated. An unlevel and not square project will have its effect on every step of the project.

Conclusion and Future Projects

Overall, this project was a huge success. The strength of the structure is outstanding and is tied to the ground with 6 reinforced 2ft deep piers that sit below the frost line and an additional 6 concrete embedded cross braces that provide moment force resistance in a type of structure that is notorious for lack of moment support and warping. Once the framing was all tied together with the 4”x6” beams,

rafters, upper cross braces, and blocking, there was no movement when any forces were placed on the structure. The shade structure provides around 96 square feet of shade in the training field and provides a rain sheltered area for equipment to be stored in the case of inclement weather. Aside from the height of the structure it replicated the style of the rest of the field's structures very closely.

For any future shade structures some changes would be made. First would be the height, lowering the structure from 9ft to 8ft, down to 8ft to 7ft would be recommended. This way the structure would keep the ideal 2:12 roof pitch while not standing unnecessarily tall. Replacing the 4"x4" posts with 6"x6" posts would also be ideal, the 4"x4" posts are the part of the structure that will likely be structural compromised given enough time. A higher quality roofing metal would also add durability to this structure. The sheets used for this structure, although cost effective, were flimsy and easily damaged.

Appendix A

Figure 1&2. Completed Lean to Shade Structure

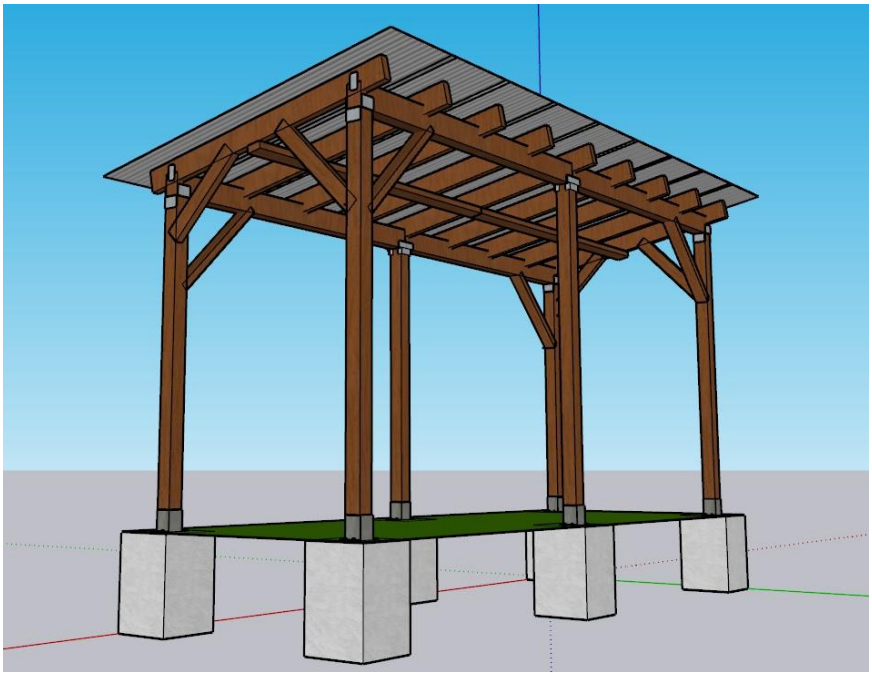

Figure 3. Early Rendering, Excluding Cross Braces

Figure 4. Formwork Set

Figure 5-7. Foundation Hardware

Figure 8. 4”x4” Posts and Embedded Cross Braces Set

Figure 8&9. 4”x6” Beam and Rafter Framing

Figure 10&11. 2”x6” Rafters (Left) and Blocking (Right)