

**NEPAL HOUSING OPTIONS - HUMANITARIAN  
PROJECT ID: CEEN\_2018CPST\_005**

**by**

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**A Capstone Project Final Report**

**Submitted to**

**Bishnu H. Adhikari**

**<Click to enter name of Sponsor's Organization>**

**Department of Civil and Environmental Engineering  
Brigham Young University**

**April 15, 2019**

## **Executive Summary**

**PROJECT TITLE:** NEPAL HOUSING OPTIONS - HUMANITARIAN  
**PROJECT ID:** CEEEn\_2018CPST\_005  
**PROJECT SPONSOR:** Bishnu H. Adhikari  
**TEAM NAME:** ABBA Consulting

More than half of the world population lives in substandard housing -- no running water, no proper sanitation or cooking facilities. There have been multiple efforts from engineers, architects, and planners in addressing this global issue, however, with little success. There are two major reasons that many lack access to affordable housing and continue living in such a poor environment: limited building material options and limited finances.

There is a massive reconstruction effort ongoing in Nepal to rebuild the private homes and public infrastructure damaged in the 2015 earthquake. A recent survey shows that bricks, rocks, and concrete are the most commonly used materials for reconstruction. There are no or very few alternative materials available for masonry walls other than bricks.

Engineers can make a difference in the production and use of alternative construction materials in improved low-cost building designs. Due to the lack of awareness on the availability and use of alternative construction materials, people in developing countries often use the same materials (bricks, untreated wood, and concrete) year after year. Use of these materials in their raw forms makes construction tedious, expensive, labor-intensive, and time consuming.

The objective of this project is to develop a list of alternative materials available in developing countries, study their present production technologies and find areas of cost-effective options for improving the quality of production. Once a preferred material was identified, it was used as the primary structural material in a secondary school design.

This process was carried out over the course of two semesters: Fall 2018 and Winter 2019. The first semester served as an exploratory period for potential materials, and the second was the design phase. Final deliverables for the project include this report, a presentation summarizing the process and results, architectural plans, and structural plans.

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## **Introduction**

The sponsor of the Nepal Housing Options project is Bishnu Adhikari, a prominent humanitarian leader. Mr. Adhikari grew up in a small Nepalese village in the Himalayas, obtained two master's degrees in engineering and environmental policy, and worked with humanitarian organizations such as the World Bank, Asian Development Bank, USAID, and CHOICE Humanitarian.

According to the project description provided by Mr. Adhikari, more than half of the world population lives in substandard housing – no running water, no proper sanitation or cooking facilities. There have been many efforts by engineers, architects, and community planners to address the global issue of substandard building quality. Two major reasons for the continuing deficiency are limited building material options and restrictive finances.

To contribute to the solution of these two issues, the project is focused on improving existing building technologies and materials to increase performance and reduce cost. The final deliverables initially included a list of five materials for homes or secondary schools with structural analysis for each. However, after further discussion with the sponsor and faculty mentor, the scope was altered. Our team was tasked with researching and evaluating alternative wall materials based on their present availability, cost-effectiveness, and production quality, and then using one of the best performing materials to produce architectural and structural plans for a secondary school.

This project is part of a larger, ongoing effort to assist the reconstruction effort in Nepal following a devastating 7.8 magnitude earthquake in April 2015. Over the course of several days, the area experienced two earthquakes over magnitude 7 and many aftershocks. Nearly 9,000 people died, thousands were injured, and tens of thousands lost their homes. Four years later, the country is still fighting to recover due to political frictions, mounting debt, and the sheer mass of damage.

Nepal's struggling economy and population also mean that the supply of raw materials for building homes and other structures is limited. A recent survey shows that bricks, rock, and unreinforced concrete are the most commonly used construction materials for reconstruction. Few alternative materials are available for structural walls that are both low-cost and seismically resistant. Therefore, our team has made sure to prioritize affordability and accessibility in our material evaluation process. Another priority in our evaluation has been a material's resistance to seismic events and other natural conditions prevalent in the area.

Overall, the team compared and contrasted existing technologies with recent research and new ventures to find the best options for a structural material. After a process of evaluating alternative building materials such as recycled plastic blocks, mycelium walls, and rammed earth, bamboo was identified as an ideal candidate for building design given the following reasons: bamboo's low cost and renewability, the material's flexibility and seismic resistance, and that it could be treated for water and pest resistance with borax. Basic material analysis was combined with existing literature to estimate the structural capacity of various configurations of bamboo. Multiple bamboo trunks can be combined to suit column and beam demands. Demands and capacities were evaluated using standard structural codes, such as NDS, the Indian Building Codes, and the Nepal Building Code.



The team developed a design for a secondary school that can act as a test-bed for bamboo structural design while also containing portions that can be easily adapted for residential use. The school design was formed with considerations for a 7.0 magnitude earthquake loads and wind loads based on conditions in the Nepalese highlands.



*Figure 1. Swayambhunath Stupa ruins after 30 April 2015 earthquake.*

The team hopes that this research and design process will serve as a springboard for further testing and prototype construction. Reductions in cost, environmental impact, and disaster risk can complement improvements in strength, seismic resistance, and ease of construction to facilitate the rebuilding of struggling communities. Subsequent design iterations can then be implemented in other regions where disasters, natural or man-made, have struck.

## Schedule

### **Phase 1: Research**

Week 1

October 8, 2018  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

Week 2

October 15, 2018  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

[Regular Status Report #2](#)

Week 3

October 22, 2018  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

[Regular Status Report #3](#)

Week 4

October 29, 2018  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

[Regular Status Report #4](#)

[Monthly Nepalese Culture Education Experience #1](#)

[Select 5-6 materials selected for further analysis](#)

November 1, 2018

### **Phase 2: Analysis**

Week 5

November 5, 2018  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

[Regular Status Report #5](#)

Week 6

November 12, 2018  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

[Regular Status Report #6](#)

Week 7

November 19, 2018  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

[Regular Status Report #7](#)

Week 8

November 26, 2018  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

[Regular Status Report #8](#)

[Monthly Nepalese Culture Education Experience #2](#)

Week 9

December 3, 2018  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor



Week 10 December 10, 2018 assignments	Team Meeting: Follow-up on previous week's assignments and make new assignments  30% Completion Report Compile all known material properties and costs into a spreadsheet. Rank materials according to properties and cost. Finish design of school.
Week 11 December 17, 2018 assignments	Team Meeting: Follow-up on previous week's assignments and make new assignments  Contact Sponsor Monthly Nepalese Culture Education Experience #3
Week 12 Christmas Break	
Week 13 Christmas Break	
Week 14 January 7, 2019 assignments	Team Meeting: Follow-up on previous week's assignments and make new assignments  Contact Sponsor Begin first draft of structural analysis spreadsheet
Week 15 January 14, 2019 assignments	Team Meeting: Follow-up on previous week's assignments and make new assignments  Contact Sponsor
Week 16 January 21, 2019 assignments	Team Meeting: Follow-up on previous week's assignments and make new assignments  Contact Sponsor Finish architectural design of school.
Week 17 January 28, 2019 assignments	Team Meeting: Follow-up on previous week's assignments and make new assignments  Contact Sponsor Monthly Nepalese Culture Education Experience #4 Complete final draft of structural analysis spreadsheet
Week 18 February 4, 2019 assignments Contact Sponsor	Team Meeting: Follow-up on previous week's assignments and make new assignments  Begin analyzing school with structural analysis spreadsheet.

**Phase 3: Testing**

Week 19

February 11, 2019  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

Week 20

February 18, 2019  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

Week 21

February 25, 2019  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

Monthly Nepalese Culture Education Experience #5

Week 22

March 4, 2019  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

Week 23

March 11, 2019  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

Finish Analysis on Classroom

Week 24

March 18, 2019  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

**Phase 4: Conclusion**

Week 25

March 25, 2019  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

Finish Analysis of Main Building

Week 26

April 1, 2019  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

Finish full structural plans and structural report.

Week 27

April 8, 2019  
assignments

Team Meeting: Follow-up on previous week's assignments and make new

Contact Sponsor

Finish PowerPoint, poster, and presentation

Finish Final Report

## **Assumptions & Limitations**

Our team made several assumptions in the initial stages of the project. This was due to the fact that Mr. Adhikari was out of the country and preparing to move his family to the states. The team was able to meet with him personally, present initial progress, and discuss the direction and scope of the project. It was after this point that the team's focus became the set of architectural and structural plans.

Based on the number of materials from initial brainstorming sessions, the team evaluated some 15 items that would be available in Nepal. The research found was done by several individuals, universities, companies, etc. that have already tested these materials we chose to research. The limitation of this approach was that Mr. Adhikari had a much clearer vision of availability and preference. Also, the research reviewed may have used a subset of the material not available in Nepal. For example, mycelium bricks could have been made by a species of mushroom that is not native to Nepal.

Another issue faced was selection of the alternative material. Since bamboo hasn't been tested in the United States, primarily because it's not grown naturally here, limited information about material properties was difficult to find. Significant amounts of research were required to find the material properties and fulfill the scope of the project to find alternative and sustainable materials. This research was successful and finding a composite material incorporating bamboo. One big issue faced that wasn't entirely resolved was the factors of safety that the NDS code requires to multiply by these factors depending on the species of wood, climate, etc.

The team felt that a major limitation during the project was that no team member had taken the timber design class from the university. Although several team members had experience in structural design or had worked for firms that focused on residential design, this lack of institutional knowledge slowed the process down as analysis implied extensive methods evaluation through trial and error. The general direction that needed to be taken was understood, but the derivation of the equations and the key concepts were troublesome on occasion. Overall, the team feels that their analysis is valid, but should be reviewed by a licensed structural engineer, preferably one with experience in bamboo construction.

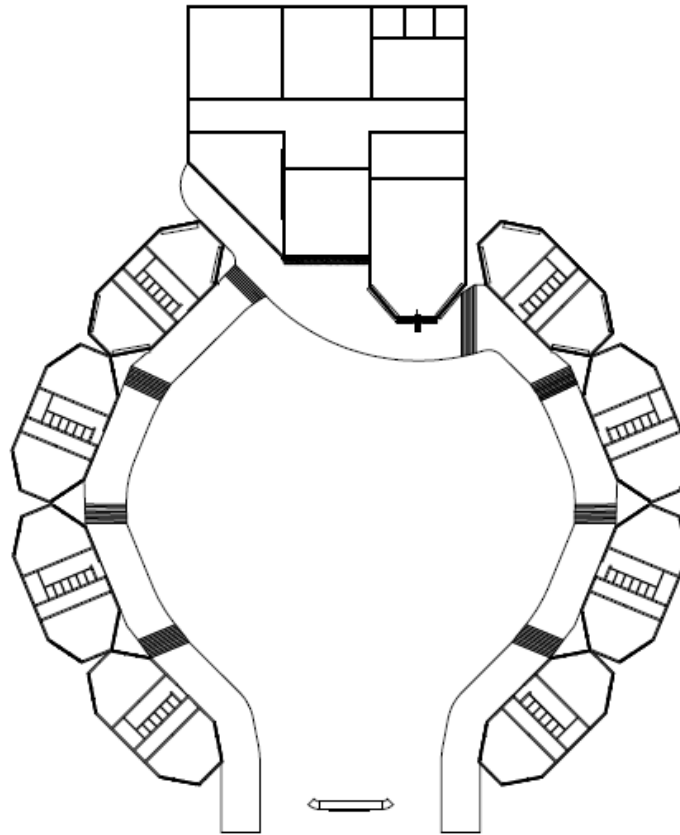
One final assumption made was the size of the school. Our school was made with the intentions to fill about six full classroom size of students of the equivalent United States middle school ages (11-14). It could be that most Nepali schools are only one to two classroom sizes and therefore, the design is too big. To account for this, the classrooms are somewhat modular, and buildings can be added or removed to adjust to specific circumstances.

## **Design, Analysis & Results**

The design for this project is two-fold: architectural and structural. We are to design a school and home for the average person living in Nepal and to determine a seismic resistant material that is cost-effective for them to use.

### **Architectural Design**

Architectural design is based loosely on Nepali structures already in existence, but it has been modified to allow for easier application in a variety of situations. The initial design featured a U-Shaped school with a multipurpose building at the head and classrooms flanking. This design was modified by opening the U to a full circle to resemble the marigold garlands given in Nepal as honorific emblems. By opening the design, a larger courtyard could be implemented reducing the need for an indoor gym while also increasing the amount of social space.



*Figure 2: School Layout – Plan View*

In addition to opening the courtyard, rounding out the layout allowed for modular classroom buildings. Instead of one long building with multiple classrooms, individual classroom units were developed each with two classrooms, a bathroom, and storage space. These units can not only be



arranged differently to accommodate the need for more classrooms but can also be placed at different elevations. By terracing the site, this classroom design can be adapted to most sites regardless of the slope.



*Figure 3: Render of Classroom Stacking*

Alongside the garland design, inspiration for other design choices was drawn from Nepali culture. Most obvious was the stacked roof structure used on the main building above the entrance. By layering bamboo beneath it, a façade was developed to resemble the Buddha eyes present in Nepali design. Carved wooden posts were planned for outside use, but with the prominent use of bamboo, these were harder to implement. While there is still room for their use, this design featured columns comprised of clusters of bamboo instead.



*Figure 4: Use of Bamboo and Nepali Detailing*

## Material Selection

To determine which materials were most viable, the team researched cost, availability, and material properties of each possible material. The material properties that were prioritized were compressive strength, tensile strength, and shear strength. These values are shown in Table 1. There are several material properties that were difficult to find due to the lack of research done about them or their availability. This is represented by blanks in the table. Additionally, many of the prices are the prices that would be found in the United States. These prices may not be accurate in Nepal. With these limitations, we are merely using our research as a place to begin narrowing down our list of potential materials.

*Table 1. Material Evaluation Values*

	Identity			Engineering Values		
	Material Name	Composition	Unit Weight	Compressive Strength	Tensile Strength	Shear Strength
<b>Concrete Alternatives</b>	Mycelium Bricks	Mycelium (mushroom)	40 kg/m <sup>3</sup>	30 psi	34-55 kPa	83-241 kPa
	Hempcrete	Hemp Hurd, Lime, Water	275 kg/m <sup>3</sup>	0.02-1.22 MPa	0.12-0.23 MPa	Negligible
	Rammed earth	Clay, Earth, Wood Forms	2000 kg/m <sup>3</sup>	>2 MPa	Equations recorded elsewhere	Equations recorded elsewhere
	Plastic bricks	Plastic	100g	10-30 MPa	13-22 KPa	
	Cob	Unburned Clay Masonry	1860 kg/m <sup>3</sup>	1.6-1.9 MPa	Negligible	
	Wrapped Concrete	Carbon Fiber, Concrete	2200 kg/m <sup>3</sup>	55-100 MPa	3.5-8 MPa	9.5-27 MPa
<b>Wood Alternatives</b>	Straw bales	Straw		6.9 MPa	Negligible	
	Bamboo rods	Bamboo	666 kg/m <sup>3</sup>	53 MPa	153 MPa	15 MPa
	Laminated bamboo beams	Bamboo, Resin	686 kg/m <sup>3</sup>	77 MPa, 22 MPa	90 MPa, 2 MPa	16 MPa
	Bamboo scrimber	Bamboo, Resin	1163 kg/m <sup>3</sup>	86 MPa, 37 MPa	120 MPa, 3 MPa	15 MPa
	Bamboo corrugated sheet	Bamboo, Resin	710 kg/m <sup>3</sup>		39.72 MPa	
	Fiberglass (roofing or walls)	Fiberglass	95 lb/ft <sup>3</sup>	140-250 MPa	55-300 MPa	55-300 MPa
<b>Conventional Materials</b>	Concrete	Standard Concrete	2300 kg/m <sup>3</sup>	12-80 MPa	2-5 MPa	6-17 MPa
	Wood	Douglas Fir	350-900 kg/m <sup>3</sup>	4-34 MPa	2 MPa	5 MPa
	Brick	Clay	1300-1700 kg/m <sup>3</sup>	25-60 MPa	9.5 MPa	
	Steel	Steel	7500-8500 kg/m <sup>3</sup>	350-1000 MPa	370 MPa	600-900 MPa



We then ranked the materials according to cost, availability, and material properties. To find an overall ranking we scaled the importance of cost, availability and material properties as 1:1:2 respectively. The material's ability to resist seismic and vertical loads is the most important characteristic, but it must also be affordable and available for people in Nepal. At the January meeting with the sponsor, bamboo was identified as the preferred material.

## **Structural Analysis**

The loads used in the structural analysis were found using the Nepal Building Code (NBC). The snow loads came from NBC 106 and the roof live loads came from IS 875 Part 2 as referenced in NBC 103. The most conservative roof live and snow loads were used. The roof live load governed with at approximately 32 psf or 1.5 kN/m<sup>2</sup>. The roof dead load was approximated according to the weight of the bamboo. The dead weight that was used was 15 psf or 0.72 kN/m<sup>2</sup>.

The beam calculations were done according to the Nepal Building Code (NBC) section 112. The specifications for wood used as the material properties for bamboo. The permissible stresses used were found in table 8 of NBC 112 and Group C was assumed, it being the most conservative. To determine the max stresses of the beams, a program entitled Forte was used. However, this software only size dimensional lumber or LVL beams; therefore, it was requisite that the bending stress, shear stress, and deflection be converted to match the area, modulus of elasticity and moment of inertia of a bamboo beam. The beams were created by stacking multiple plies of bamboo. The beams are called out as the number of bamboo plies base by height (# of bamboo plies across X # of bamboo plies deep).

The limit for the deflection of beams in the NBC is  $L/360$ . While bamboo is strong axially, it is very weak in bending and, therefore, deflection governed for all beams. Several beams needed to become very deep to resist the deflection. To reduce depth, the diameter of the bamboo plies was decreased thus allowing more bamboo material and less space between them. To ensure the beam acts uniformly, additional engineering will be required to design the connection between the plies. Additionally, our original design for the roof layout failed because the deflection was too great for the ridge beams. The solution to turn the direction of the span of the rafters to be parallel to the ridge and to provide girder rafter every 4.5 meters to decrease load on the beams.

As part of the required deliverables, a set of full structural plans were provided. This includes roof framing, shear and foundation plans for both the main building and the classroom. Each wall, beam, and column are called-out and a schedule is provided for each load resisting system.

The calculations that were run to determine the capacities of the studs in the bearing walls and the columns were done in accordance with National Design Specification for Wood Construction (NDS) 2015 code. Regarding the bearing walls, the tributary width was calculated using the distances that spanned have way between the walls and any beams that ran parallel with the bearing wall in question. With the walls that run parallel with the rafters, the tributary widths were smaller compared to the walls running parallel to the rafters. Using the roof live and dead loads, the distributed loads were determined for each of the walls in both the classroom and the main office building. The code calls for three limit states to be tested; one, pure compression due to axial forces

from the roof, two, lateral forces using the governing load combinations acting as a beam column incorporating axial and either earthquake or wind, and three, a combination of these three with the unknown question of which lateral load will be greater. The load combinations used in the calculations are found in the ASCE 7-10. Load combinations #2, #5, and #6a were used in this project.

The bearing wall calculations were derived from the equation 3.9-3 found under Section 3.9.2, “Bending and Axial Compression.” The equation appears as Figure 5.

$$\left[ \frac{f_c}{F_c'} \right]^2 + \frac{f_{b1}}{F_{b1}' \left[ 1 - (f_c/F_{cE1}) \right]} + \frac{f_{b2}}{F_{b2}' \left[ 1 - (f_c/F_{cE2}) - (f_{b1}/F_{bE})^2 \right]} \leq 1.0$$

*Figure 5. Bending and axial compression equation used for bearing walls.*

The second half of this equation became zero due to a lack of biaxial bending caused by another lateral force. The studs, trimmers, and king studs are undergoing a combination load. Since these combinations behave nonlinearly, they are hard to predict. Mathematically calculated Eqn. 3.9-3 incorporates the combination of the compressive strength and the actual compressive stress, the bending strength and the actual bending stress. If the capacities calculated known as the  $F_c'$  and  $F_{b1}'$  are greater than the demands  $f_c$  and  $f_{b1}$ , then the final value of Eqn. 3.9-3 will be less than 1.0, and the design is OK-passes. If the stud walls didn't pass at certain locations, then the spacing was adjusted from 12 in. (30cm) to 8 in. (20cm) to incorporate less tributary area thus weakening the lateral load effect on each of the wall studs. In particular, the walls in the main office building were hard to calculate because of their height.

The column calculations also followed the NDS design requirements. However, the derivation of the equation in the code is a little different than the one used for beam-columns. Chapter 3 of the NDS 2015 code book was used. A Column Stability Factor,  $C_P$ , was used to determine if the column will undergo buckling while being installed or after immediate loadings are put on them. The formula appears as Figure 6.

$$C_P = \frac{1 + (F_{cE}/F_c^*)}{2c} - \sqrt{\left[ \frac{1 + (F_{cE}/F_c^*)}{2c} \right]^2 - \frac{F_{cE}/F_c^*}{c}}$$

*Figure 6. Column stability factor equation used for column buckling.*

With this formula, the design allows for the material strength to be conservative to avoid the buckling effect on columns since they aren't supported laterally to fight against lateral buckling. The capacity for the column was determined by multiplying the actual compressive strength, given by the company discussed hereafter, and the area desired for design is less than the compressive strength of the material. This value is given as a stress in psi ( $N/mm^2$ ). If this value is greater than the compressive strength of the material, then the design passes.

Material properties were the hardest data to acquire. A company named Lamboo that manufactures a composite structural material of bamboo, known as plyboo, was used in all calculations for vertical members. Lamboo provided the compressive strength, bending strength, and modulus of elasticity of plyboo that was used in the calculations.

Shear calculations were based on a combination of code from the Nepal Building Code, the Indian Building Code, and National Design Specifications for Wood Construction. Since design wind speeds vary by more than 20 meters per second across Nepal, the highest speeds from the highlands were selected to provide conservative estimates. Wind loads were calculated using the methods in the Indian Building Code. This methodology considers wind direction, internal and external air pressures, and building geometry. Since the modular classrooms can be expected to experience wind from any direction, maximum loadings were selected to govern capacity.

Earthquake loads were calculated using accelerations common across research in the country and represent a magnitude 7.0 earthquake. The National Design Specification methods were used to evaluate conservative estimates for forces. The resulting linear loads were comparable or less than associated wind loads, and thus the team expects that the structures will perform similarly under each load combination involving wind and earthquake.

Shear wall capacity was obtained using resources from the American Plywood Association design documents. When properly connected to the structure, OSB has the potential to provide capacity that exceeds demand by 300% - 400%. However, given the material properties of bamboo, a typical nailing schedule of two to three inches may cause splitting. For this reason, the team recommends using wood screws with a greater spacing, see structural plans for more details.

## **Lessons Learned**

Many lessons have been learned during the course of this capstone project. One was learning to make engineering judgments in an area that the team previously had little experience in. Several of the team members had previous experience with light-frame wood construction, but they still needed to learn how to apply that experience to an uncommon building material. Due to the sparse information available on bamboo strength, especially in comparison to the well-established timber industry in the US, there were several challenges that slowed down the analysis process. One of which was needed to create a set of spreadsheets to run calculations that existing software would have been able to do with a wood structure. The team learned to adjust to a new material and learned the necessary calculations to ensure the structural integrity of the school. If the team had been able to establish working assumptions earlier in the project, it may have removed some challenges that pushed deadlines later in the project.

Communication with our sponsor has been limited which impacted our understanding of the life in Nepal as well as the feasibility of certain facets of the project. To understand further the team researched other organizations that have done work in Nepal to assess the feasibility of the project. Analyzing the economic status and the average income provided by resources on the internet about Nepal was sufficient for the initial research stages. The team collaborated as a group extensively and compared multiple different ways to make up for the lack of information and expertise. The team feels that the scope of the project has been met as best as we have been able.

## **Conclusions**

In our research, the team developed a catalog of potential structural materials and selected bamboo as the most promising. This was due to its fast growth and structural properties. From the body of research read, it appears that bamboo has the potential to be a competitive material for general construction. This is further supported by the speed at which the material grows, allowing for renewable harvesting, local production, and low turn-around times.

There have been difficulties in obtaining local costs and availability, making our cost comparison less precise. There was also a less substantial volume of work on the material properties of bamboo when compared with materials more traditionally used in construction projects in the US. However, the team is confident that the final product will be usable in the real world as a testbed for more efficient and cost-effective structures.

Architectural and structural plans were produced for a secondary school using bamboo as the primary structural material. Bamboo can be utilized to improve earthquake resistance while reducing the risk of injury in a failure given the lighter material weight. As covered in this report, the design of the complex is meant to complement the project's Asian heritage while also providing several other benefits to the end users.

The team feels that various aspects of the school's design could easily be modified for other purposes such as housing, government offices, or medical facilities. This complements the flexibility of the complex design and will hopefully be able to reduce the amount and cost of design work required over the plans' lifespan.

Despite the difficult processes, sparse background information, and heavy workloads, the team has enjoyed the project. Each team member was pushed to learn and grow in several ways, and the experience in working through challenges as a group was incredibly beneficial. It is the team's hope that this project will be useful in the recovery efforts in Nepal and in other rebuilding efforts across the world.

## **Recommendations**

Based on the challenges faced, assumptions made, and the analysis performed, the team makes the following recommendations.

- Evaluation of code-based structural design assumptions based on construction location. Since a significant portion of the design process relied on the Nepal and Indian Building Codes, construction in other locations should be preceded by an evaluation of the design given local building standards.
- Lab-testing of bamboo rod configuration, bamboo-bamboo connections, bamboo-foundation connections, and borax treatment effectiveness to ensure desired performance. Given the lack of a well-established body of academic and industry research on the material properties of the species of bamboo that will likely be used in construction.
- Review of structural calculations by a licensed structural engineer. None of the team members for this project are professionally licensed, and thus an engineer with experience in the area should review the demands and capacities of the design before construction takes place.



## **Appendix A**

## ADAM FOULK

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### Education

<b>Bachelor of Science</b> - Civil Engineering	April 2020
Brigham Young University	Provo, UT
<ul style="list-style-type: none"> <li>GPA 3.26</li> <li>Europe Infrastructure and Global Leadership Study Abroad – selected by a board of professors from many applicants for the first summer BYU offers this program.</li> <li>Achieved position in the Beyond Measure Vocal Group on campus</li> </ul>	
<b>Associate Degree</b> - General Studies	May 2016
Eastern Arizona College	Thatcher, AZ
<ul style="list-style-type: none"> <li>GPA 3.69</li> <li>Graduated with honors</li> <li>Graduated on Dean's list</li> <li>Awarded Presidential Full Ride Scholarship for Academics</li> </ul>	<ul style="list-style-type: none"> <li>Awarded Half Tuition Scholarship for Music</li> <li>Awarded "Mr. Physics" for 100% on test</li> <li>Awarded Scholarship for Vocal Lessons</li> </ul>

### Professional Experience

<b>Brigham Young University</b>	Provo, UT
<i>Teaching Assistant – Mechanics of Materials, Metals, Woods &amp; Composites</i>	January 2018 - Present
<ul style="list-style-type: none"> <li>Mentored 160 students on process to find stress and strain, moments of inertia, and torsion forces on structures</li> <li>Collaborate with professor and team of TAs to optimize and expand student understanding</li> </ul>	
<b>Brigham Young University</b>	Provo, UT
<i>Research Assistant - Mortar Design</i>	September 2017- December 2017
<ul style="list-style-type: none"> <li>Performed tests on mortar compressive strength for breaking points and vulnerability with different additives.</li> <li>Delivered results to a Las Vegas construction company to improve sustainability.</li> </ul>	
<b>Earthtech Engineering</b>	Lindon, UT
<i>Engineering Intern - Geotechnical</i>	February 2017- August 2017
<ul style="list-style-type: none"> <li>American Concrete Institute (ACI) Certified as concrete technician and handle radiation equipment</li> <li>Ensured quality performance of compressive strength tests on concrete cylinders, soil compaction tests, and lab sieve tests</li> <li>Traveled across Utah to various locations speaking Spanish to continue work production</li> </ul>	
<b>Project Engineering Consultants</b>	Phoenix, AZ
<i>Engineering Intern – Water Resource Management</i>	May 2016-August 2016
<ul style="list-style-type: none"> <li>Analyzed video data for defects in over 200 miles of sewer pipe and manholes for the City of Phoenix</li> <li>Reviewed billing records for errors in company's organization and acquired documents from local city records departments.</li> </ul>	

### Professional Skills

- Fluent in Spanish (speaking, writing, reading, and interpreting)
- Programs: ArcGIS, SAP 2000, AutoCAD, Revit, Pipe LOGIX, Microsoft Office
- Coding language: Visual Basic (major), Script Editor (Google sheets-minor)

### Leadership Experience

- Earthquake Engineering Research Institute (EERI)– Structural Design Captain for EERI competition in Los Angeles
- American Society for Civil Engineers (ASCE) – regular attendance and participation in humanitarian aids to local groups
- Global Engineering Outreach (GEO) – Installment of water system and adobe house on Navajo Reservation.
- Structural Engineering Association of Utah (SEAU) – webinar instruction of structural code improvements.
- GuyZ Vocal Group – Beat Boxer for select small ensemble group of skilled singers from among a few hundred
- Boy Scouts of America (BSA) – Completed Eagle Scout Rank, highest rank one can receive.
- Tenor II Section Leader A Capella Choir – Instructed group to read solfedge, improved sight reading and vocalizing
- Eastern Arizona Engineering Club – Secretary – managed meetings and organized "Engineering Day" activities for hundreds of high school students in the Gila Valley region of Arizona to spark an interesting in engineering.



## Braiden Green

Civil Engineering Student  
Architecture Emphasis

818.825.7868  
443 N 100 E  
Provo, UT, 84606  
braidenbfgreen@gmail.com

## TECHNICAL SKILLS

AutoCAD	● ● ● ● ●	Photoshop	● ● ● ● ●
Revit	● ● ● ● ●	Illustrator	● ● ● ● ●
Dynamo	● ● ● ● ●	MS Office	● ● ● ● ●
Matlab	● ● ● ● ●	VBA	● ● ● ● ●

## EXPERIENCE

### Upwall Design Architects

Architectural Draftsman | Jun. 2017 - Current | SLC, UT  
*Prepared construction documents for client/city approval*  
*Modeled custom homes and furniture in Revit*  
*Trained new employees in Revit and production standards*

### BYU Center for Advanced Structural Composites

Research Assistant | Aug. 2016 - Apr. 2017 | Provo, UT  
*As a research team, developed new methods of carbon fiber rebar manufacture.*  
*Designed lab equipment increasing production capabilities by 500%.*

### Blue Line Deli & Market

Asst. Kiosk Supervisor | Aug. 2015 - Apr. 2016 | Provo, UT  
*Trained a team of 30 employees in customer service.*  
*Led a bi-weekly council of supervisors to improve production and efficiency.*  
*Responsible for strategy, marketing, production, inventory management, and customer service.*

### BYU Men's Chorus Presidency

Activities & Projects Manager | Apr. 2016 - Apr. 2017 | Provo, UT  
*Coordinated the organization of retreats, tours, and other activities for 200 - 400 people.*  
*Organized publicization of the choir through print, web, and school of music public affairs.*

## EDUCATION

### Brigham Young University

B.S. Civil & Environmental Engineering  
*Expected Graduation: Apr. 2019*

# Bryce C. Miller

717 Wymount Terrace, Provo, UT 84604  
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linkedin.com/in/brycecurtismiller

## SKILLS

Surveying & Land Measurement  
Statistical Analysis  
Building & Site Review  
Demographic Analysis & Projection  
Ordinance Writing  
Public Meeting Organization  
Transportation Engineering & Planning

## SOFTWARE PROFICIENCIES

AutoCAD  
Revit  
ABAUUS  
ArcGIS  
ArcMap 10  
Synchro  
Microsoft Office Suite  
Adobe Creative Suite  
VBA  
Python

## EDUCATION

**Brigham Young University** Expected Graduation: April 2019  
B.S., Civil Engineering Provo, UT  
Minor in Urban Planning  
• GPA 3.57  
• Scholarship: U.S. Department of Veteran Affairs DEA Scholarship

## PROFESSIONAL EXPERIENCE

**City of Orem** June 2018-Present  
*Planning Intern* Orem, UT  
• Update zoning ordinance language for the City  
• Enforce zoning code through meetings with citizens and written notices  
• Attend public meetings and committees as a member of staff to advise public officials  
• Manage GIS data entry for Development Services department

**Civil Engineering Department, BYU** September 2017-September 2018  
*Research Assistant* Provo, UT  
• Researched the effects of material properties through finite element analysis in ABAQUS CAE  
• Analyzed and summarized research findings for report

**City of Madison** May 2017-August 2017  
*Planning Intern* Madison, AL  
• Assisted with the development of the Industrial Master Plan  
• Analyzed local demographic trends for public officials  
• Reviewed site and building plans for approval by the City  
• Performed research for long range planners

## VOLUNTEER EXPERIENCE

**Church of Jesus Christ of Latter-day Saints** May 2013-May 2015  
*Full Time Representative* Greater Philadelphia Region

**Boy Scouts of America** October 2006-Present  
*Member & Counselor* Atlanta, GA; Huntsville, AL

## PROFESSIONAL ASSOCIATIONS

**American Society of Civil Engineers,** September 2015-Present  
*National and BYU Student Chapter*  
**American Planning Association** June 2018-Present  
**BYU Student Urban Planning Association** September 2017-Present

# ABBEY WILSON

abbeywilson08@gmail.com • (801)633-4449 • 592 W 940 N Provo, UT 84606

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## EDUCATION:

<b>Bachelor's Degree, BS</b>	Provo, UT
Civil and Environmental Engineering	Dec. 2019
Brigham Young University – 3.66 GPA	
<b>Associates Degree of Science</b>	Logan, UT
Utah State University – 4.0 GPA	May 2013

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## WORK EXPERIENCE:

<b>Student Engineer</b>	Orem, UT
<i>Acute Engineering</i>	Jan. 2018-present

- Design residential houses to withstand all lateral and vertical loads applied to them
- Create custom details to provide load transfer in unique circumstances
- Communicate structural design using Auto Cad and PDF drawings

<b>Student Engineering Intern</b>	Provo, UT
<i>Provo City Public Works</i>	Jan. 2017-Dec. 2017

- Assist city engineers in the design and execution of road design projects
- Manage the addressing of Provo City by updating their GIS map and supplying the needed legal documents for address change
- Quantify materials needed to create accurate bid documents
- Inspect public roadways for the development of future projects and the releasing of bonds

<b>Research Assistant</b>	Provo, UT
<i>Harold B. Lee Library</i>	May 2016-May 2017

- Execute projects regarding the women's movement using library databases and resources
  - Prepare research for editing and publication by compiling annotated bibliographies, writing essays, and creating PowerPoint presentations
  - Coordinate often with professor to unify vision yet work independently to fulfil expectations
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## VOLUNTEER EXPERIENCE:

<b>Design Coordinator</b>	Provo, UT
<i>Global Engineer Outreach</i>	Aug. 2017-May 2018

- Work on an interdisciplinary engineering team to design a soapmaking process for entrepreneurial women in Peru
- Executed changes to formula based of the availability of resources and client feedback
- Instructed women on soapmaking process and safety measures