

Nepal Earthquake Recovery -- Housing Options
PROJECT ID: CEEN_2018CPST_005

by

ABBA Consulting
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A Capstone Project 30% Completion Report

Submitted to

Bishnu Adhikari
DUDBC

Department of Civil and Environmental Engineering
Brigham Young University

December 10, 2018

Executive Summary

PROJECT TITLE: NEPAL EARTHQUAKE RECOVERY – HOUSING OPTIONS
PROJECT ID: CEEEn_2018CPST_005
PROJECT SPONSOR: Bishnu Adhikari – DUDBS
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.

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 keep using the same materials (bricks, untreated wood, and concrete) over and over. Use of these materials in raw form makes construction tedious, expensive, labor-intensive, and time consuming.

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.

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 quality of production. Use one of the low-cost housing designs and carry out thorough structural analysis for five alternative construction materials for walls.

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Introduction

The Nepal Housing Options project is a humanitarian project focused on improving existing building technologies and materials in order to increase performance and reduce cost. Our team has been tasked with researching and evaluating alternative wall materials based on their present availability, cost-effectiveness, and production quality. The final deliverable will be a list of five materials for homes or secondary schools with structural analysis for each. Further discussion with faculty has indicated that full, real-world analysis may not be possible. However, our team intends to provide as much research and analysis as is feasible.

Nepal's struggling economy and population mean that the supply of raw materials for building homes and other structures is limited. 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's goal is to compare and contrast existing technologies with recent research and new ventures to find the best options for structural use in Nepal.

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 Complete first draft of structural analysis spreadsheet Finish design of home.
Week 15 January 14, 2019 assignments	Team Meeting: Follow-up on previous week's assignments and make new assignments Contact Sponsor Complete second draft of structural analysis spreadsheet
Week 16 January 21, 2019 assignments	Team Meeting: Follow-up on previous week's assignments and make new assignments Contact Sponsor Analyze school and house with structural analysis spreadsheet.
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 Select 3 of the most cost-effective and seismic-resistant materials for in depth research.
Phase 3: Testing Week 19 February 11, 2019 assignments	Team Meeting: Follow-up on previous week's assignments and make new assignments Contact Sponsor

Week 20
February 18, 2019
assignments

Begin lab testing as needed.

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

Contact Sponsor

Begin optimization- Combining materials or changing how they are installed

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

Report of Constructability of Materials

Week 23
March 11, 2019
assignments

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

Contact Sponsor

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

Monthly Nepalese Culture Education Experience #6

Week 26
April 1, 2019
assignments

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

Contact Sponsor

Finish proposal of most effective materials.

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 quite a few assumptions before proceeding into the project we have completed thus far. The reasoning for these assumptions is because we haven't been able to formally meet Mr. Adhikari and present our ideas while comparing them to what he truly wants. These assumptions are our interpretations of the information given to us by him since the beginning.

Based on the number of materials, we decided to present some 15 items that we thought would be available in Nepal. As a result, the research reported here was done by several individuals, universities, companies, etc. that have already tested these materials we chose to research. The limitations with this approach is that Mr. Adhikari is likely to have a better idea of the materials he wishes us to research into and those that are available. Also, the research teams that tested the material we have chose might have used a particular branch of the material we had in mind that is not the same material available in Nepal. For example, the mycelium bricks could have been made by a different type of mushroom that isn't in Nepal.

Another assumption made was the way we would determine if the material was actually available in Nepal. Some research was done for these materials by selecting companies already in business in Nepal that have utilized these materials. This, however, limits us more in depth knowledge about whether or not the materials these companies used are available for the average Nepali citizen instead of those that only live in the city areas or individuals that can actually afford these material pricing. More research about the economics available for the average Nepali citizen will be done to help refine the materials' availability.

One final key assumption made was the design 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. It could be that most Nepali schools are only one to two classroom sizes and therefore, our design is too big. Our limiting knowledge of Nepal without actually visiting there or speaking with someone who is native to Nepal.

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 is based loosely upon Nepali structures already in existence modified to allow for easy structural application. For the secondary school, we decided upon a U-shaped building, with classrooms lining the two legs of the U, and administrative offices and a common meeting hall centered on the base. To simplify structure, column layout is based upon early Christian basilica structure. This eliminates structural offloading to any kind of buttress and creates a directional focal point to the room allowing for the common meeting hall to be utilized for school and community assemblies.

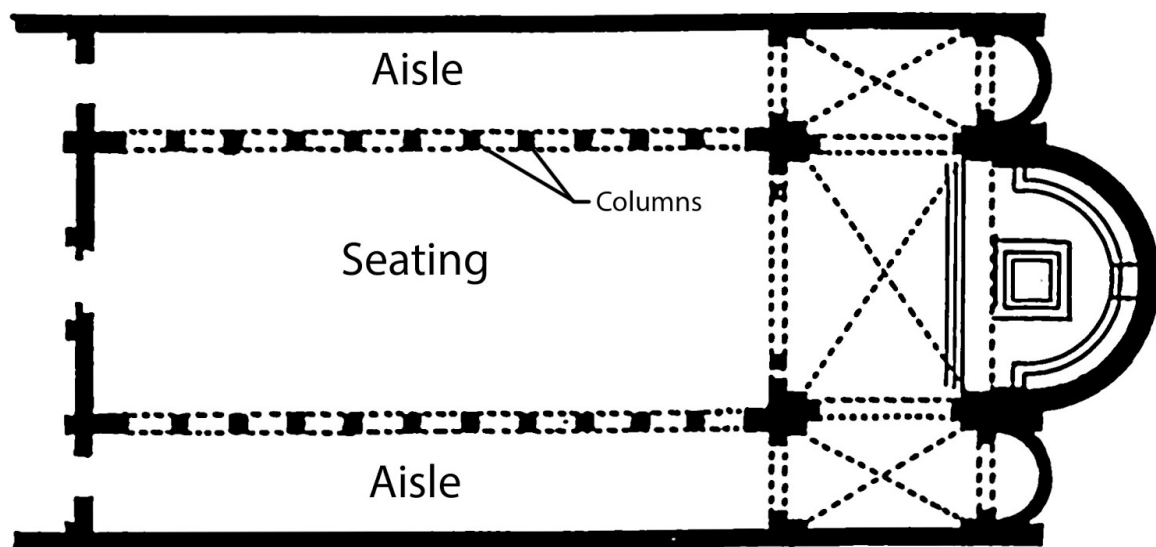


Figure 1 Basic Basilica Form

The classrooms and administrative offices feature a double-roof structure visually similar to many existing Nepalese structures. This roof was designed to create an atrium-like feel to the classrooms, with high clerestory windows allowing for natural light to filter in at all times of day, reducing the need for electric lighting in the school.



Figure 2 Example of Nepali Roof Structure

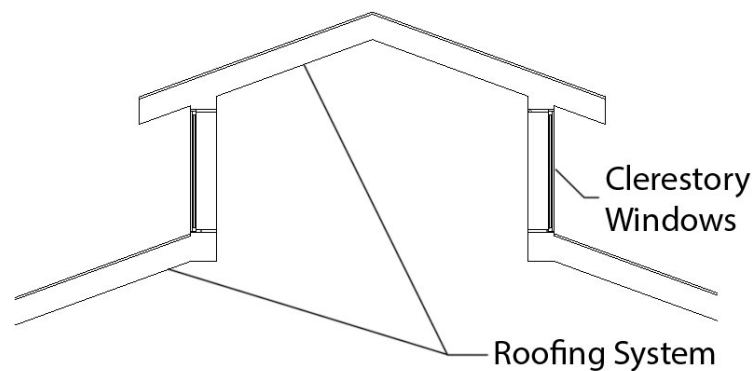


Figure 3 Double-Roof Detail for Classrooms

To determine which materials were most viable, we researched the cost, availability and material properties of each possible material. The material properties that we were most interested in are the compressive strength, tensile strength and shear strength. These values are tabulated below. There are several material properties that were difficult to find due to the lack of research done about them or their availability. This is the reason that there are several 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 Alternative Building Material Properties

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

We will rank the materials according to its cost, availability and material individually. To find an overall ranking we will scale 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. We will use this select the materials that we will continue to research.

Lessons Learned

There have been quite a few lessons we have learned. One of the biggest is not utilizing our resources as best as we could. We have not been able to communicate very much with Mr. Adhikari and this limits our understanding of the civilian life in Nepal as well as the exact scope of our entire project. Since we have not been able to visit or communicate with him that much, the best thing we have done is research from other organizations that have done work in Nepal. These companies haven't responded to us either, but we have pressed forward. Analyzing the economic status and the average income provided by resources on the internet about Nepal have suited our needs thus far.

Having a project with a sponsor that lives out of country with a 12 hour time zone difference is particularly difficult to overcome. However, we have collaborated together as a group and compared multiple different ways to make up for the lack of meetings with our sponsor simply do to natural reasons. And yet, the scope of our project, we can confidently say, is being met with much enthusiasm and determination to do the best job we can. We are satisfied with our results thus far.

Conclusions

In our research, we have developed a catalog of materials with potential as well as initial floor plans for a home and secondary school. Further research in each items' material properties and structural analysis will be the primary focus for the upcoming Winter semester. Additionally, team members will finalize the floors plans for analysis, continue economic and availability research for the materials, and collate the research and analysis into a single document. This document will be reviewed by the faculty mentor and the project sponsor. Overall, it seems that there are several promising materials, such as bamboo, that could be utilized to improve earthquake resistance while reducing the risk of injury in a failure with lighter materials. There have been difficulties in obtaining local costs and availability, making our cost comparison less precise. However, the team is confident that the final product will be usable in the real world a resource for evaluating building material options.

Due to the nature of the sponsor's work, the team has had limited contact and feedback on progress thus far. The team hopes to have further interaction in the coming months to ensure that the deliverables fulfill the needs of the client as fully as possible given any surrounding circumstances.

Appendix A

Bryce C. Miller

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SKILLS

Surveying & Land
Measurement

Statistical Analysis

Building & Site
Review

Demographic
Analysis &
Projection

Ordinance Writing

Public Meeting
Organization

Transportation
Engineering &
Planning

SOFTWARE PROFICIENCIES

AutoCAD

Revit

ABAQUS

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

ADAM FOULK

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Education

Bachelor of Science - Civil Engineering Brigham Young University	April 2020 Provo, UT
- GPA 3.26 - Europe Infrastructure and Global Leadership Study Abroad – selected by a board of professors from many applicants for the first summer BYU offers this program. - Achieved position in the Beyond Measure Vocal Group on campus	
Associate Degree - General Studies Eastern Arizona College	May 2016 Thatcher, AZ
- GPA 3.69 - Graduated with honors - Graduated on Dean's list - Awarded Presidential Full Ride Scholarship for Academics - Awarded Half Tuition Scholarship for Music - Awarded "Mr. Physics" for 100% on test - Awarded Scholarship for Vocal Lessons	

Professional Experience

Brigham Young University <i>Teaching Assistant – Mechanics of Materials, Metals, Woods & Composites</i>	Provo, UT January 2018 - Present
- Mentored 160 students on process to find stress and strain, moments of inertia, and torsion forces on structures - Collaborate with professor and team of TAs to optimize and expand student understanding	

Brigham Young University <i>Research Assistant - Mortar Design</i>	Provo, UT September 2017- December 2017
- Performed tests on mortar compressive strength for breaking points and vulnerability with different additives. - Delivered results to a Las Vegas construction company to improve sustainability.	

Earthtech Engineering <i>Engineering Intern - Geotechnical</i>	Lindon, UT February 2017- August 2017
- American Concrete Institute (ACI) Certified as concrete technician and handle radiation equipment - Ensured quality performance of compressive strength tests on concrete cylinders, soil compaction tests, and lab sieve tests - Traveled across Utah to various locations speaking Spanish to continue work production	

Project Engineering Consultants <i>Engineering Intern – Water Resource Management</i>	Phoenix, AZ May 2016-August 2016
- Analyzed video data for defects in over 200 miles of sewer pipe and manholes for the City of Phoenix - Reviewed billing records for errors in company's organization and acquired documents from local city records departments.	

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

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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

ABBEY WILSON

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

EDUCATION:

Bachelor's Degree, BS

Civil and Environmental Engineering
Brigham Young University – 3.66 GPA

Provo, UT

Dec. 2019

Associates Degree of Science

Utah State University – 4.0 GPA

Logan, UT

May 2013

WORK EXPERIENCE:

Student Engineer

Acute Engineering

Orem, UT

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

Student Engineering Intern

Provo City Public Works

Provo, UT

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

Research Assistant

Harold B. Lee Library

Provo, UT

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
-

VOLUNTEER EXPERIENCE:

Design Coordinator

Global Engineer Outreach

Provo, UT

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