PROJECT REPORT

FOR

VIRUNGA COFFEE.COCOA CO-OP
NORTHERN PROVINCE, RWANDA

01 JULY 2018

PREPARED BY:

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NOTE: NOT FOR CONSTRUCTION. TO BE REVIEWED AND APPROVED BY IN-COUNTRY ENGINEER.
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1.0 Abstract

Through the help of Journeyman International, local cooperatives, and the Empowering Villages Organization, a large part of Rwanda is being redesigned and rebuilt. Changes hope to enable access to electricity, and will empower communities with leading socio-economic development solutions in energy, environment, entrepreneurship, and education. These efforts have led to the vision of the Virunga Coffee/Cocoa Co-op along the Mukungwa River in the Northern Province of Rwanda. This project consists of a team of two Architectural Engineering students, an Architecture student, and a Construction Management student from California Polytechnic State University in San Luis Obispo, CA, working with a local representative in Rwanda. The purpose of this project is to create a community center and warehouse for the advancement of coffee and cocoa farming that locals can access for both learning and economic empowerment in order to increase education standards and employment in the community. This project report consists of a personal reflection of travel experiences in Rwanda, preliminary research of the history of Rwanda, drawings and calculations of the structure, challenges faced during the project, and reflections of personal encounters throughout the project.
2.0 Introduction

2.1 What is Journeyman International/Brief Overview

Journeyman International is a nonprofit humanitarian design organization that pairs university students and future designers with organizations and countries that are in need of good architecture and design. Students studying architecture, engineering, construction management and/or landscape architecture are given the opportunity to work on these projects to fulfill their senior thesis requirement. Journeyman International strives to inspire and excite students by doing humanitarian work all over the world. In fact, many of these Journeyman International projects are found outside of the country, thus giving students a chance to travel abroad and get first hand experience of the culture, land, and people. Through its efforts, Journeyman International aims to change the lives of both the students and the people of these communities.

2.2 Situation/Background

Rwanda is on the forefront for building locally and sustainably in developing countries. This can be seen through recent Journeyman International projects such as the Women’s Aquaculture Cooperative and the Sunzu Village. Increased education has led to advancements in construction and engineering that promote environmentally conscious strategies to solve problems in the country. Rwaza, Musanze, in the Northwest province, faces problems concerning energy and socioeconomic growth. The Virunga Coffee-Cocoa Co-Op is working in conjunction with the Empowering Villages organization and DC Hydropower to create more energy and jobs.
in the area and to continue Rwanda’s mission on sustainability. Empowering Villages is a nonprofit organization working with the Global Giving Organization, which is the largest global crowdfunding community connecting nonprofits, donors, and companies in nearly every country. Materials for the community center building are found directly at the site and use building practices as old as time, such as rammed earth walls.

Empowering Villages’ ultimate mission is to enable access to electricity and empower communities with leading socio-economic development solutions in energy, environment, entrepreneurship, and education. Specifically, Empowering Villages is also engaged with the Rwaza Hydropower Plant to fulfill its socio-economic mission to better the lives of the surrounding community. This joint effort has led to the creation of a project that will provide a community center/learning space and a warehouse next to the hydropower plant on the Mukungwa River in the North West of Rwanda. This report will focus specifically on the design of the community center. The design team for this project includes architecture student Dayna Lake, construction management student Tanner Frkovich, and two architectural engineering students Anugrah Gupta and Caleb Azevedo. All four members are graduating seniors at California Polytechnic State University in San Luis Obispo, working to
create more job opportunities and education for the community, and to perpetuate coffee farming in Rwanda.

Project Site Map - Virunga Coffee/Cocoa Co-op

2.3 Story of Travel

Anugrah is grateful for the opportunity to travel to Rwanda in December 2017. He was able to see the current state of his project site, as well as meet and interact with many local Rwandans who are the main motivation for Anugrah’s dedication to humanitarian work.

In addition to meeting influential people and seeing his project site, Anugrah had many other heartwarming experiences. In 1994, Rwanda went through a horrible genocide, which resulted in the death of over one million people. While in Kigali, Anugrah visited the Rwandan
Genocide Memorial, where some 250,000 people are interred. Having this experience at the beginning of the trip was a major factor in the emotional attachment that Anugrah was to have with the people of Rwanda. In addition to visiting the memorial, Anugrah noticed a great sense of pride among the people of Rwanda; their focus was more to overcome their losses rather than grieve them. Furthermore, given the 1994 tragedy, the people were surprisingly welcoming to tourists and other outsiders. This further inspired Anugrah to dedicate his time and passion to this project.

Of the many villages visited, Sunzu Village in Northern Province, Rwanda was the most memorable for Anugrah. Sunzu is the site of a previously designed (and constructed) Journeyman International project, as well as the current construction site for another Journeyman project. The completed project is a multi-use building designed to provide a place for children and women to meet and learn, in an effort to promote education in one of the poorest regions of Rwanda. When Anugrah arrived, children were either playing outside, in the library reading stories aloud in English, or learning how to use various computer software. The faces of these kids lit up with immense joy as Anugrah and the rest of the Journeyman team arrived. Many pictures were taken, games played,
stories read, and memories made. To this day, Anugrah is pen pals with a thirteen-year-old student at Sunzu named Didier Niyomukiza.

Each and every day in Rwanda was filled with unforgettable adventures whether they were visits to beautiful and vast Lake Kivu, or getting chased by elephants in Rwanda’s Akagera National Park. Anugrah feels a great sense of appreciation for the culture and people of Rwanda and is extremely passionate about helping the country by means of yet another Journeyman International project.

2.4 Preliminary Research

Although Caleb did not travel to Rwanda with others in December of 2017, he still performed preliminary research of the history of Rwanda and also watched the movie “Hotel Rwanda” as recommended by Journeyman International president Daniel Wiens. Rwanda is a
country located in the northern province of Africa with a population of approximately 11.2 million people. The capital is Kigali, which can be found in the center of the country.

Prior to 1994, two groups represented much of the country: the Tutsis and the Hutus. Both groups had similar physical characteristics and religious beliefs. After World War I, Rwanda came under the League of Nations mandates of Belgium, and during the Belgian colonization the Belgians favored the Tutsi minority over the Hutus (Rwandan Genocide, History.com). The Tutsis were perceived to have greater wealth and were granted higher social status than the Hutus by the Belgians (Lichfield, Independent). This created ethnic strife as the Hutus believed that the Tutsis were privileged and could not be trusted. Rebellious Hutus revolted, forcing many Tutsis to leave the country and declaring the country as a republic. Violence continued throughout the years. The military then declared a moderate Hutu, Juvenal Habyarimana, in power of Rwanda. He then became the president of the political party, the National Revolutionary Movement for Development (MRND). In 1990, negotiations between the Rwandese Patriotic Front (consisting mainly of Tutsis) and Habyarimana led to a reconstruction of the Rwandan government that would include the Tutsis which angered the Hutu extremists and caused tensions to rise even higher (Rwandan Genocide).

On April 6, 1994, Rwandan President Juvenal Habyarimana and Burundi President Cyprien Ntaryamira were murdered as their plane was shot down over Kigali (Rwandan Genocide). This culminated in the Rwandan genocide as Hutu militia known as the Interhamwe and Rwandan armed forces began murdering innocent Tutsis and moderate Hutus. Approximately 800,000 Tutsis and moderate Hutus were killed by these forces in a span of 100 days (Rwanda Country Profile, BBC News).
During this time, the international community stayed on the sidelines; the only international assistance the country received came from the French troops who provided safe zones for the Tutsis and helped some escape. The people of Rwanda were helpless, because the United Nations failed to intervene as they saw Rwanda as less important than other countries. Innocent lives were unrightfully taken; the United Nations could have helped more than they did. Though portrayed by actors, “Hotel Rwanda” showed the emotions and the challenges the country faced.

Today, Rwanda still remembers those whose lives had been taken, but also looks to the future of the country. A farmer in Rwanda, Ezekial Shinga, states “Everything in this country has changed. People own businesses, and the majority are tea farmers. There’s peace, and neighbors now love each other (Onnyulo, The Washington Times).” Tea and coffee have been the main reasons for the recent economic growth, and this growth has helped provide currency to the country for new construction of schools, hotels, and other infrastructure (Rwanda Country Profile). The goal is to continue the economic growth and strive for better educational opportunities for the future of Rwanda. Caleb and the rest of the Journeyman International team look to fulfill this goal through the efforts of the Virunga Coffee/Cocoa Co-op.
3.0 Project Description

3.1 Coordination Approach/Assumptions

Coordination throughout the course of this project was very crucial, as there are many limitations when designing in Rwanda as opposed to the U.S. In addition, a lot of information was unavailable to the team that was project-specific. For example, there were no soil reports available for the exact location of the proposed building. Therefore, the engineering team used soil reports from previous projects within 50 km of the Virunga site. With the use of these reports, the team classified the soil and extracted bearing pressures and other coefficients necessary for the design of the foundation.

All communications for this project were conducted between the architecture student, Dayna, and the on-site representatives. The on-site representatives included Carly Althoff and Daniel Klinck, both of whom are permanently situated in Rwanda. To keep communication precise and limited, the engineering team, Anugrah and Caleb, gathered information they needed from the representatives and relayed it to Dayna. As a result, all proposed questions (including those from Dayna) were asked in a single phone call/email approximately once every two weeks, or as otherwise needed.

Another major aspect of the design that needed to be approved by and communicated with the on-site representatives was material use. The initial phase of the project consisted of communication amongst Dayna and the representatives in coordinating what building materials were available for the use of the design. The second phase involved the engineering team communicating ultimately with the representatives in determining material strengths and
properties. The J.I. team concluded that many of the material properties for this project would be similar to previous projects. However, one difference was the compressive strength of rammed earth walls: 1,500 psi as opposed to a more commonly used strength of 4-5,000 psi for concrete. Although some information was found on the internet, the team knew it was more accurate to obtain this information first hand. Therefore, Anugrah was able to incorporate in the design materials that he saw when he traveled to Rwanda. The project therefore consists mainly of the following materials: corrugated metal roofing, timber roof joists, steel roof beams and columns, reinforced rammed earth walls, and reinforced concrete foundations.

Preliminary Materials List

3.2 Drawings and Calculations

The calculations can be found in Appendix A, and the drawings in Appendix B. For the first section of this calculation package, the engineering team determined an overall framing layout and performed a roof load take-off for the structure. In addition, they designed the slab-on-grade, roof joists, and beams. As reflected in the calculations, there are many materials
being used simultaneously. This initially created conflict with member sizes and connections of members in terms of constructability. In addition, loads and member spans governed the design, making the layout increasingly inefficient. As a result, the engineering team used a roofing system including dimensional lumber joists in conjunction with steel wide-flange beams, as opposed to exclusively timber framing. Preliminary designs were also taken into account in order to determine seismic weight and wall layout.

The slab-on-grade consists of a typical design that is commonly used for 1-2 story buildings in California. Due to minimal design loads, this design is applicable. The joists were designed using dimensional lumber, specifically *Douglas Fir-Larch No. 3* grade. Regarding available materials in Rwanda, the team felt this grade was the best comparison. A distributed load of 68 pounds per linear foot (plf) spans across the entire joist. Temperature and moisture effects were negligible, and therefore factors were accordingly set to 1.0. The joist design includes checks of bending, shear, and deflection. The final design of the joists is 2x10s at 24 in. on-center.

The roof beams were designed using A992 steel, with a yield stress of 50 ksi and an ultimate stress of 65 ksi. Due to large spans, steel is a more efficient material than timber for the roof beams. A uniform distributed load of 488 plf acts along the entire span of both designed beams. Bending, shear, and deflection were checked for each beam. Beam B1 is designed to be a W18x40 and Beam B2 is designed to be a W14x22.

The second section of this calculation page includes the design of wide flange columns and column foundations. Much of the gravity load is transferred to the rammed earth walls through bearing except for the south-most section of the building. Dayna wanted to have rammed
earth walls that would disconnect from the roof to provide for openings and natural light throughout the community center. In response, the engineering team added columns along that grid-line to support the W14x22 roof beams.

The column selected for design was the “worst-case” column (the tallest column) which has an unbraced length of 17 feet. The column was also designed using A992 steel. The loads used for this design were a dead load of 20 pounds per square foot (psf) and live load of 14 psf. The live load could not be reduced because the tributary area of the column was lower than the minimum, as was the slope of the roof. The tributary area affecting the column was 10 feet by 16 feet, or 160 square feet. The demand gravity load using the tributary area and load combination for LRFD was 7.84 kips.

The capacity values for the column design came from the AISC 14th Edition Steel Manual. “Pin-pin” connections were assumed as the base for the column, which resulted in a K value of 1.0. The column was designed to be a W10x33 with an axial load capacity of 195 kips.

The column footing was designed with reference to the ACI 318-14 code. The footing was designed using concrete and steel reinforcing; the compressive strength of the concrete was 3,000 psi and the yield strength of the reinforcing was 60 ksi. The engineering team was not able to find sufficient soil information for the site, but used previous projects’ soil reports; therefore, the assumed soil classification used for this design was expansive clay soil with an allowable soil pressure of 1.5 kips per square foot (ksf). This pressure is also the worst-case scenario per the International Building Code (IBC) 2015. Under service loads, the area required for this footing was 4 ft². For conservative purposes, the team designed a 4’x4’ square footing with an area of 16
The depth of the footing is 2 feet which was acceptable for two-way action shear and wide-beam action shear.

The footing reinforcement design was similar to that of a concrete slab. The demand moment from the soil pressure on the footing was 2.25 kip-ft. The required area of the steel was 0.03 in$^2$; therefore, the footing required minimum reinforcement per ACI standards which was 2.07 in$^2$. The design team tried (5) #6 reinforcing bars with a total area of 2.20 in$^2$. Spacing requirements were checked for both shrinkage and temperature reinforcement, and flexural reinforcement under ACI standards. The provided spacing of the footing reinforcement is approximately 9.5 inches. To ensure ductile behavior, steel should yield before concrete. This assumption was checked as a part of this calculation as the steel strain was 0.076 in/in which is greater than the yielding steel strain of 0.0021 in/in. Using the ACI 318-14, the moment capacity of the column footing was 195 kip-ft. To assume adequate development length within the concrete footing, 90-degree standard hooks shall be used.

The third section of this calculation package includes the lateral design criteria and design of two specific shear walls and their respective foundations. With the final architectural designs of the walls completed by Dayna, the engineering team computed the seismic weight of the building which included the roof dead load and shear wall self-weights. The engineering team used half of each shear wall self weight because the other half would transfer directly to the ground. Seismic criteria is documented in the load take-off section of the design package. The engineering team concluded that the seismic base shear of the building is 14 kips in both directions.
The engineering team verified that wind loading did not govern the lateral design. Using the ASCE 7-10 code, they performed a wind analysis to find the maximum pressures on the building. The engineering team used the lowest wind pressures in the United States (California, at 110 mph) due to inadequate data regarding wind pressures in the project’s region; previous J.I. teams have used the same pressures. After all of the parameters were checked, the engineering team concluded that the base shear for wind is 12 kips in the North-South direction and 9 kips in the East-West direction. As a result, seismic loading governs in the lateral design at 14 kips.

Using the seismic lateral loads, the engineering team designed the shear walls. Based on the layout of the building, they designed one shear wall in each direction of loading (East-West and North-South). The shear walls will be constructed of rammed earth, and therefore a conservative estimate for the design strength of this material was used. As a result of conducting research and looking at past projects, a lower bound compressive strength of 1,500 psi was used and the walls were designed using the same process as reinforced concrete walls.

The shear wall designs include sizing and spacing of shear reinforcement, flexural reinforcement, and boundary element confinement. Due to extremely low seismic loads in comparison with California, the shear walls were designed using minimum code-enforced reinforcing. In addition, no special boundary reinforcement was required, as the lateral loads were relatively small in the East-West and North-South directions (3 kips and 7 kips, respectively). In order to eliminate the iterative process of designing flexural reinforcement, spColumn was used to check the flexural capacities of the wall sections.

After the design of the shear walls, the engineering team designed their respective foundations. Again, in order to eliminate the iterative process of designing reinforcement, the
team used a self-created excel spreadsheet that expedited the process. The spreadsheet roughly goes through the design process and makes intermediate checks along the way which helps the designer understand the general foundation dimensions. The design can then be started using these dimensions, and the need for iteration is eliminated.

The shear wall foundation designs consist of soil bearing pressure checks, flexural reinforcement design, and transverse reinforcement design. Due to past experience with shear wall foundation designs, the team did not check/design shear reinforcement; shear reinforcement is extremely uncommon in shear wall foundations unless loads are unusually large. Therefore, the relatively small seismic loads allowed for the use of minimum reinforcing in both directions of the shear wall foundations.

For the soil bearing pressure checks, two load cases were considered: one with solely dead and live loads, and another including seismic effects in addition to dead and live loads. These load combinations were used in conjunction with an Allowable Stress Design (ASD) approach. The reinforcement, however, was designed using Load and Resistance Factor Design (LRFD).

3.3 Challenges

One of the main challenges the engineering team faced was coordination with Dayna. Initially, the team wasn’t given much information from her due to the lack of general knowledge on the location. In their lab courses, the engineering team was accustomed to general project information such as materials and site information (seismic, wind, and soil criteria). The
beginning stages of the project had many changes in material use and footprint, which prevented the engineering team from conducting accurate load take-offs and preliminary calculations for the structure.

Dayna and engineering team had trouble deciding what materials to use for the project; for example, Dayna wanted to design the roof framing with timber for aesthetic appeal, while the engineering team believed that steel framing would be structurally efficient. The project initially consisted of a range of materials that the engineering team had not encountered being used simultaneously. Although the design could have been carried out using these materials, the engineering team and Dayna discussed the inefficiencies involved. As a result, the materials were re-chosen to solve the structural issues while still allowing for aesthetic freedom. A draft design was created using plywood sheathing, timber framing, rammed earth walls, and steel columns. However, during the calculation phase, the engineering team determined that timber framing would be difficult to use due to large spans. Therefore, steel wide flange beams are used in the gravity system. This change allowed Dayna to have more vertical clearance with smaller beam depths, while also reducing complications in the framing system for the engineering team.

As stated earlier, there were little to no reports available regarding site conditions of Rwanda. In order to overcome this challenge, the engineering team used similar U.S. wind conditions for this project. The seismic criteria, on the other hand, was taken from a report analyzing seismic loads in Bujumbura and Kigali (Ndihokubwayo, Jiang, and Chen, 2). The site design criteria taken were conservative in comparison with the actual seismic and wind conditions in Rwanda. The soil criteria were taken from minimum requirements in the 2015 edition of the IBC.
Another challenge was the unfamiliarity with the design of connections between members of varying materials. Additionally, the general procedure of designing rammed earth shear walls was unknown. To overcome these challenges, research was conducted which included reading a 2003 article on the construction of rammed earth walls (Maniatidis & Walker, 2003). Daniel Wiens also recommended to the engineering team using the same design approach as with concrete shear walls; the only difference being a reduced compressive strength of 1,500 psi.

3.4 Status/Future of Project

The architectural, structural, and construction packages will be submitted and reviewed by Journeyman International, and the calculations will be thoroughly reviewed by (an) in-country engineer(s). Land has already been allocated for the project and construction will hopefully begin after fundraising is complete. In upcoming months, the Journeyman International team, especially those who did not have the opportunity to travel in December of 2017, will hopefully travel back to Rwanda to gain further understanding on the current status of the project.
4.0 Conclusion

4.1 Personal Reflection - Anugrah Gupta

After ten weeks of working on the design of Virunga Coffee/Cocoa Co-op, I can proudly say that I was able to incorporate much of what I have learned at Cal Poly over the years. With the completion of three structural design labs and the combination of various materials in the building concept, I was well-trained to complete the design. Many challenges arose along the way, but I was able to overcome these challenges using the help of my teammates, as well as my engineering judgement. The Virunga Coffee/Cocoa Co-op was a very interesting building to work on due to the large range of materials used, especially because some were new to me (i.e. rammed earth). However, this served solely as additional motivation, and it gave me the opportunity to learn and incorporate new ideas into the project.

For me, this project was more than a graduation requirement, but rather a comprehensive examination of what I have been taught over the last four years. Most importantly, this was an incredible opportunity and privilege for me, as the community center could possibly be constructed one day. Additionally, the opportunity I was given to travel to Rwanda will remain with me for a lifetime. Not only was I able to gain firsthand knowledge of my site, but was also able to get a great sense of appreciation for the culture and people of Rwanda. Journeyman International is an incredible organization that I hope to continue working with after graduation; the opportunities are endless, and there is no other organization that gives students the confidence to design their own structure with the possibility of construction.
4.2 Personal Reflection - Caleb Azevedo

Working with Journeyman International was a great opportunity for me because it introduced me to what working on actual structural projects feels like. From scheduling weekly meetings to coordinating and adapting to changes in design, I understand that when it comes to working on an actual project, it is more than calculations and drawings. I encountered challenges with new materials such as rammed earth and also with designing connections between different materials that I was not accustomed to. These challenges were difficult, but with the help of research, assistance from professors, and consultation with my engineering partner Anugrah, the design challenges were resolved.

I realize that not travelling to Rwanda this past winter made it difficult to understand what this project actually means. My preliminary research taught me about the unfortunate events that occurred in Rwanda. With no assistance from any other nations, Rwanda was helpless. But through all the pain and suffering in 1994, Rwanda has grown as a community today. I am proud to be a part of this process. With coffee being one of the primary sources for economy in Rwanda, the Virunga Coffee/Cocoa Co-op project will increase jobs and economy.

I feel that this senior project has prepared me for the future. I will be starting work at Strandberg Engineering and am excited to utilize everything that I have learned throughout my four years at Cal Poly. I will also still be interested in working with Journeyman International after graduation because it allows me to combine design with humanitarian work that will benefit those that need it. I hope that I will be able to go visit the Rwandan project site and continue to be a part of the design of the Virunga Coffee/Cocoa Co-op.
Appendix A - Calculations
STRUCTURAL CALCULATIONS
FOR
VIRUNGA COFFEE CO-OP
NORTHERN PROVINCE, RWANDA

Virunga A COFFEE // COCOA CO-OP RWANDA, AFRICA

01 JULY 2018

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  SLAB ON GRADE E/W SLIDING CHECK.............................L27
PROJECT DESCRIPTION:
THE PROJECT CONSISTS OF A SINGLE STORY, MULTI-MATERIAL COMMUNITY CENTER FOR COFFEE AND COCOA FARMING LOCATED IN THE NORTHERN PROVINCE OF RWANDA, AFRICA. THE ROOF IS MADE UP OF STAND SEAM METAL ROOFING.

THE GRAVITY SYSTEM CONSISTS OF DIMENSIONAL LUMBER JOISTS THAT REST ON STEEL WIDE FLANGE BEAMS. THE FRAMING SITS ON RAMMED EARTH BEARING WALLS AND STEEL WIDE FLANGE COLUMNS. THE COLUMN FOUNDATIONS ARE REINFORCED CONCRETE SPREAD FOUNDATIONS. THE INTERIOR OF THE BUILDING IS SLAB-ON-GRADE.

THE LATERAL SYSTEM CONSISTS OF 3/8" PLYWOOD SHEATHING SPANNING TO RAMMED EARTH SHEAR WALLS IN BOTH DIRECTIONS. THE SHEAR WALLS ARE SUPPORTED BY REINFORCED CONCRETE SPREAD FOUNDATIONS.

DESIGN CRITERIA:

DESIGN CODE: 2015 IBC
ASCE 7-10
ACI 318-14
AISC STEEL MANUAL 14TH EDITION
NDS/SDPWS 2015

BUILDING TYPE: TYPE II - OCCUPANCY CATEGORY B

WIND CRITERIA*: 110 MPH, EXPOSURE B

SEISMIC CRITERIA**: SDS = 0.190g
R = 5.0 (ORDINARY CONCRETE SHEAR WALLS)
SEISMIC DESIGN CATEGORY B
IMPORTANCE FACTOR (IE) = 1.0

SOIL CRITERIA***: ASSUMED EXPANSIVE CLAY SOIL
SITE CLASS D ASSUMED
ALL EXCAVATIONS, FILLING, BACKFILLING, AND SOIL COMPACTION PER GEOTECHNICAL REPORT: NOT AVAILABLE
ALLOWABLE PASSIVE SOIL PRESSURE: 100 PSF/FT
ALLOWABLE VERTICAL FOUNDATION PRESSURE: 1500 PSF
COEFFICIENT OF FRICTION: 0.3

*WIND CRITERIA BASED ON WORST CASE UNITED STATES CONDITIONS PER ASCE 7-10. SEE APPENDIX C.
**SEISMIC CRITERIA BASED ON SCHOLARLY ARTICLE. SEE APPENDIX C.
***NO SOILS REPORT GIVEN. WORST CASE CONDITION USED PER IBC SECTION 1602.4. SEE APPENDIX C.
LOAD TAKE-OFF

GRAVITY

<table>
<thead>
<tr>
<th>Description</th>
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</tr>
<tr>
<td>Roof Underlayment</td>
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</tr>
<tr>
<td>Weatherproofing</td>
<td>1.0</td>
</tr>
<tr>
<td>3/8&quot; Plywood Sheathing</td>
<td>2.0</td>
</tr>
<tr>
<td>Misc.</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>9.0</td>
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</tbody>
</table>

Framing                              | 5.0        |
                                      | 14.0       |

SEISMIC WEIGHT

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<tr>
<td>Total Shear Wall</td>
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<td></td>
<td>362.0</td>
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LIVE LOAD

<table>
<thead>
<tr>
<th>Description</th>
<th>Load (PSF)</th>
</tr>
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<tbody>
<tr>
<td>Roof Live Load (Reducible)</td>
<td>20.0</td>
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</table>
SEISMIC WEIGHT KEY PLAN
# Seismic Weight

<table>
<thead>
<tr>
<th>Description</th>
<th>Calculation</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>14.0 psf × 77' × 72.25' /1000</td>
<td>78.0 kips</td>
</tr>
<tr>
<td>SH 1</td>
<td>125pcf × 12'' / 12 × 2 × 77' /1000</td>
<td>58.0 kips</td>
</tr>
<tr>
<td>SH 2</td>
<td>125pcf × 23'' / 12 × 12 × 13' /1000</td>
<td>11.0 kips</td>
</tr>
<tr>
<td>SH 3</td>
<td>125pcf × 36'' / 2 × 12 × 86.5' /1000</td>
<td>68.0 kips</td>
</tr>
<tr>
<td>SH 4</td>
<td>125pcf × 13'' / 12 × 4'' × 35.5' /1000</td>
<td>31.0 kips</td>
</tr>
<tr>
<td>SH 5</td>
<td>SAME AS SH 4</td>
<td>31.0 kips</td>
</tr>
<tr>
<td>SH 6</td>
<td>SAME AS SH 2</td>
<td>11.0 kips</td>
</tr>
<tr>
<td>SH 7</td>
<td>125pcf × 23'' / 12 × 4'' × 40' /1000</td>
<td>39.0 kips</td>
</tr>
<tr>
<td>SH 8</td>
<td>SAME AS SH 5</td>
<td>39.0 kips</td>
</tr>
<tr>
<td>SH 9</td>
<td>125pcf × 13'' / 2 × 2 × 19.5' /1000</td>
<td>15.0 kips</td>
</tr>
<tr>
<td>SH 10</td>
<td>SAME AS SH 8</td>
<td>15.0 kips</td>
</tr>
</tbody>
</table>

\[ EUL = 362 \text{ kips} \]
SEISMIC CRITERIA

I = 1.0
R = 6.0 (ORDINARY CONCRETE SHEAR WALL)
SITE CLASS = B
SEISMIC DESIGN CATEGORY = B
S_y = 0.28 g
F_a = 1.0
S_1 = 0.11 g
F_1 = 1.0

S_{HS} = F_a S_y = 0.28 g
S_{H1} = F_1 S_1 = 0.11 g
S_{DS} = \frac{2}{3} S_{HS} = 0.19 g
S_D1 = \frac{2}{3} S_{H1} = 0.07 g

C_S = \frac{S_{DS}}{R/4} = \frac{0.19 g}{(6/4)} = 0.038 g

C_t = 0.02
x = 0.15
h = 17.4 ft
T_a = C_t h n^x = 0.17 sec.

C_{max} = \frac{S_0}{(T \left( \frac{g}{h} \right))} = 0.08 g
C_{min} = 0.044 S_{DS} E = 0.008 g

C_S = 0.038 g

BASE SHEAR

V_3 = C_S H
V_3 = (0.038 g)(362 KIPS) = 14.0 KIPS

V_3 = 14.0 KIPS
WIND LOADING - N/S DIRECTION

STEP 0: \( h_{\text{max}} = 19' < 20' \)

1. ENCLOSED BUILDING
2. 19' ROOF HEIGHT ≤ 60'
3. \( L = 86.5' \)
   \( B = 95.5' \)
   \( \frac{L}{B} = 0.93 \) \( (0.2 ≤ 0.93 ≤ 5.0) \)
4. \( K_2 = 1.0 \)

STEP 1: RISK CATEGORY II

STEP 2: MINIMUM US \( V = 110 \text{ MPH} \) (CALIFORNIA COMPARISON)

STEP 4: \( P_1 = \frac{17.5 + 16.7}{2} = 17.1 \text{ PSF} \)

STEP 5: \( P_2 = \frac{17.2 + 16.7}{2} = 17.0 \text{ PSF} \)

STEP 5: SLOPE = 2:13 or 7:40
1.84:12 2.1:12

ADJUSTMENT FACTOR = 0.695

<table>
<thead>
<tr>
<th>FLAT &lt; 2:12</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h = 17' )</td>
<td>LC1</td>
<td>NA</td>
<td>NA</td>
<td>-24.6</td>
<td>-21.8</td>
</tr>
<tr>
<td>( h = 17' )</td>
<td>LC2</td>
<td>NA</td>
<td>NA</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

WITH ADJ: ZONE 3 = -16.8 PSF
ZONE 4 = -14.9 PSF
ZONE 5 = -12.3 PSF

\( V_{\text{MAX}} N/S = 17.1 \text{ PSF} \times \frac{19'}{2} \times 72.5' / 1000 = 120 \text{ KIPS} \)

\( V_{\text{MAX}} N/S < V_S \)
120 KIPS < 14.0 KIPS

SEISMIC GOVERNS
WIND LOADING - E/W DIRECTION

STEP 0: BUILDING IS AN ENCLOSED, SIMPLE DIAPHRAGM BUILDING

- BUILDING ROOF HEIGHT = 19' - 0" (410FT)
- L/B = 94'/18' = 1.08 (> 0.2 & < 5.0) ✓

STEP 1: RISK CATEGORY II

STEP 2: V = 110 MPH (BASED ON CALIFORNIA COMPARISON)

STEP 3: EXPOSURE CATEGORY - B
Kz = 1.0
ENCLOSED BUILDING

STEP 4: \( P_h = 16.7 + 17.5 = 17.1 \text{ PSF} \)
\[ \frac{P_0}{2} = \frac{16.7 + 17.2}{2} = 16.95 = 17.0 \text{ PSF} \]

STEP 5: 20 FT HEIGHT

LOAD CASE 1: \( P_2 = -29.5 \text{ PSF} \)
LOAD CASE 2: \( P_0 = 0.00 \text{ PSF} \)
\( P_2 = 0.00 \text{ PSF} \)

ADJUSTMENT FACTOR: 0.6845 \( \rightarrow P_2 = -16.8 \text{ PSF} \)
\( P_2 = 0.00 \text{ PSF} \)

STEP 6: NOT APPLICABLE (Kz = 1.0)

STEP 7: ASSUME \( P_h \) & \( P_0 \) = 17.1 PSF

WALL DIMENSIONS: 86.5' x 12'
WIND BASE SHEAR = 17.1 PSF (86.5' x 12'/2) = 8875 # = 9K

\[ \therefore \text{ SEISMIC LOADS GOVERN (} 14K > 9K \) \]

\[ \Rightarrow \text{ USE } V_s = 14K \]
DUE TO MINIMAL DESIGN LOADS AND A ONE-STORY BUILDING, USE A TYPICAL SLAB-ON-GRADE DESIGN AS SPECIFIED BELOW. IN ADDITION, SOIL (SUBGRADE) MUST BE COMPACTED PRIOR TO CONSTRUCTION OF SLAB.

SLAB DESIGN:
5" NET CONCRETE SLAB
#3 @ 18" o.c. EACH WAY
ON COMPACTED SUBGRADE.

(MINIMUM COVER: 1" EACH FACE)

CONCRETE: $f'c = 4000$ PSI
REBAR: $f_y = 60$ KSI
JOIST DESIGN - J1

ASSUMPTIONS: SPAN = 13 FT
DOUGLAS FIR LARCH No. 5
ALLOWABLE STRESS DESIGN

FBD:

\[ W_{D} + W_{L} = (2') (14.0 \text{ psf} + 20.0 \text{ psf}) = 68 \text{ plf} \]

BENDING

\[ M = \frac{wL^2}{8} = \frac{(68 \text{ psf})(13')^2}{8} = 1437 \text{ lb} \cdot \text{ft} \]

\[ f_{b} = \frac{M}{S} = \frac{1437 \text{ lb} \cdot \text{ft} \times 12''}{S_{\text{allow}}} = 17,244 \text{ lb} \cdot \text{in} \]

\[ F_{b} = \frac{525 \text{ psi} \times C_{D} \times C_{A} \times C_{R} \times C_{L} \times C_{F} \times C_{R} \times C_{R} \times C_{R}}{1.25 \times 1.0 \times 1.0 \times 1.0 \times 1.1 \times 1.0 \times 1.0 \times 1.15} = 830 \text{ psi} \]

\[ S_{\text{allow}} = \frac{17,244 \text{ lb} \cdot \text{in}}{830 \text{ psi}} = 20.78 \text{ in}^3 \]

\[ f_{b} = \frac{17,244 \text{ lb} \cdot \text{in}}{21.39 \text{ in}^3} = 807 \text{ psi} \]

TRY 2 x 10 24" O.C. (S = 21.39 in³)

\[ f_{b} \leq F_{b} \checkmark \]

807 psi < 830 psi \checkmark

\[ D/C = 0.972 \]

DEFLECTION

\[ \Delta_{D+L, \text{allow}} = \frac{L}{240} = \frac{13'}{240} = 0.65 \text{ in} \]

\[ \Delta_{D+L, \text{demand}} = \frac{5wL^4}{384EI} = \frac{5(68 \text{ plf})(13')^4(12')^3}{384(1,400,000 \text{ psi})(98.93 \text{ in}^4)} = 0.32 \text{ in} < 0.65 \text{ in} \checkmark \]
**Shear**

\[
V = \frac{wL}{2} = \frac{6 \times 9 \times 13 \times 12}{2} = 442 \text{ lbs}
\]

\[
f_v = \frac{V}{A} = \frac{442 \text{ lbs}}{13.88 \text{ in}^2} = 32 \text{ psi}
\]

\[
F_v' = 180 \text{ psi} \times \frac{1.25 \times 1.0 \times 1.0 \times 1.0}{1.25} = 225 \text{ psi}
\]

\[
f_v \leq F_v' \checkmark
\]

\[
32 \text{ psi} \leq 225 \text{ psi} \checkmark
\]

\[
\frac{P}{c} = 0.142 \checkmark
\]

**Self Weight Check**

\[
W = \left( \text{Specific Gravity} \right) \left( \text{Unit Weight of Water} \right) \left( \text{Volume of Member} \right) / \text{trib area}
\]

\[
w = (0.5)(62.4 \text{pcf}) \left( \frac{1.5''}{12} \times \frac{9.25''}{12} \times 13'' \right) / (2' \times 13')
\]

\[
w = 1.5 \text{ PSF} \leq 5.0 \text{ PSF Assumption} \checkmark
\]

**USE 2x10 @ 24" O.C.**

**Douglas Fir - Larch No. 3**
BEAM DESIGN - BI

ASSUMPTIONS:
SPAN = 45'-0"
ASSUMED STEEL (Fy = 50 KSI, Fu = 65 KSI)
LRFD DESIGN

PBD:

\[ 1.2W_b + 1.6W_f = [1.2(14) + 1.6(20)] \times 10' = 988 \text{ PLF} \]

BENDING:

\[ M = \frac{WI^2}{8} = \frac{(488)(45)^2}{8} = 123.5 \text{ K-Ft} \]

\[ \phi M_p = \phi M_n = 140 \text{ K-Ft} \]

\[ M_u = 123.5 + 1.2 \left( \frac{0.026 \text{ KLF}(45)^2}{8} \right) = 131.9 \text{ K-Ft} \]

\[ M_u = 131.9 \text{ K-Ft} < \phi M_n = 140 \text{ K-Ft} \checkmark \]

\[ D/c = 0.94 \checkmark \]

SHEAR:

\[ V_u = WL/2 = (488 + 1.2(0.026))(45)/2 = 11.7 \text{ k} < \phi V_n = 84.2 \text{ k} \checkmark \]

DEFLECTION:

\[ \Delta_{dis.} = \frac{9W_2L^4}{384EI} = \frac{5 \left( 0.034 (10) + 0.026 \right) (45)^4 (12)^3}{384 \left( 25,000 \right) \left( 209 \text{ in}^3 \right)} = 5.7" \left( > 2.25" \right) \]
**DETERMINE \( I_{eq} \)**

\[
2.25 = \frac{5 \left( 0.034(10) + 0.050 \right) (45)^4 (12)^3}{384 \left( 28,000 \right)} \quad \Rightarrow \quad I_{eq} = 480.8 \text{ in}^4
\]

**BENDING:**

\[
\frac{W_{bend} \times 40}{(\phi_{MN} = 274 \text{ k-ft})}
\]

\[
M_u = 123.5 + 1.2 \left( \frac{0.040(45)^2}{8} \right) = 135.7 \text{ k-ft} \quad (\leq \phi_{MN} = 274 \text{ k-ft}) \checkmark
\]

**SHEAR:**

\[
V_u = \frac{W_b}{2} = (0.488 + 1.2(0.040))(45)/2 = 12.06 \text{ k} \quad (\leq \phi_{Vb} = 146 \text{ k}) \checkmark
\]

**DEFLECTION:**

\[
\Delta_{MN,\text{min}} = 2.25''
\]

\[
\Delta_0 = \frac{W}{360} = 45(12)/360 = 1.5''
\]

\[
\Delta_{MN} = \frac{5 \left( 0.034(10) + 0.050 \right) (45)^4 (12)^3}{384 \left( 28,000 \right) (518 \text{ in}^4)} = 2.33'' \quad (\geq 2.25) \]

**TRY W18 x 40**

**BENDING:**

\[
\frac{W_{bend} \times 40}{M_u = 135.7 \text{ k-ft}} \quad (\leq \phi_{MN} = 274 \text{ k-ft}) \checkmark
\]

**SHEAR:**

\[
V_u = 12.06 \text{ k} \quad (\leq \phi_{Vb} = 146 \text{ k}) \checkmark
\]

**DEFLECTION:**

\[
\Delta_{MN} = \frac{5 \left( 0.034(10) + 0.040 \right) (45)^4 (12)^3}{384 \left( 28,000 \right) (612)} = 1.98'' \quad (\leq 2.25) \checkmark
\]

\[
\Delta_l = \frac{5 \left( 0.020 \right) (45)^4 (12)^3}{384 \left( 28,000 \right) (612)} = 0.101'' \quad (\leq 1.5) \checkmark
\]

**USE W18 x 40**
**BEAM DESIGN - B2**

**ASSUMPTIONS:**
- B2' SPAN
- A992 STEEL ($F_y = 60$ ksi, $F_u = 65$ ksi)
- LOAD RESISTANCE FORCE DESIGN (LRFD)

**FBD:**

![FBD Diagram]

**BENDING:**

\[
M_u = \frac{wL^2}{8} = \frac{483 \text{ PLF} \times (32')^2}{8} \times \frac{1 \text{kip}}{1,000 \text{ lbs}} = 63 \text{ kip-ft}
\]

\[L_b = 0 \text{ (JOISTS BRACE LATERALLY)}\]

\[\phi M_p = \phi M_n = 125 \text{ kip-ft}\]

\[M_u = 63 \text{ kip-ft} + 1.2 \left( \frac{0.022 \text{ kip/ft} \times (32')^2}{8} \right) = 86.4 \text{ kip-ft}\]

\[M_u \leq \phi M_n \checkmark\]

\[86.4 \text{ kip-ft} \leq 125 \text{ kip-ft} \checkmark\]

\[P/L = 0.83 \checkmark\]

**SHEAR:**

\[V_u = \frac{wL}{2} = 9 \text{ kips}\]

\[\phi V_n = 99.5 \text{ kips}\]

\[V_u \leq \phi V_n \checkmark\]

\[9 \text{ kips} \leq 99.5 \text{ kips} \checkmark\]

\[P/L = 0.10 \checkmark\]

**DEFLECTION:**

\[\Delta_{pl, demand} = \frac{5wL^4}{384EI} = \frac{5 \times (10' \times 34 \text{ PSF}) \times 0.022 \text{ kip/ft} \times (32')^4}{384 \times (29,000 \text{ ksi}) \times (199 \text{ in}^4)} = 1.60 \text{ in} \leq 1.60 \text{ in} \checkmark\]

\[\Delta_{dl, demand} = 0.82 \text{ in} \leq 1.07 \text{ in}\]

**USE 1114 x 22.**
COLUMN DESIGN - C1

ASSUMPTIONS: HOLLOW FLANGE COLUMN
HEIGHT = 17 FT
A_{hub} = 10' x 16' = 160 SF
L_{b} = 20 PSF
D = 14 PSF

REDUCED LIVE LOAD:
R_{1} = 1.0
R_{2} = 1.0

\[ \text{L}_{r} = L_{b} R_{1} R_{2} = 20 \text{ PSF} \times (1.0) (1.0) = 20.0 \text{ PSF} \]

LOAD COMBINATION
\[ 1.2 D + 1.6 L = 1.2 (14 \text{ PSF}) + 1.6 (20.0 \text{ PSF}) \]
\[ = 49 \text{ PSF} \]

LOAD \[ P_{u} = 49 \text{ PSF} \times 160 \text{ SF} = 7,840 \text{ lbs} = 7.84 \text{ kips} \]

\[ P_{u} = 7.84 \text{ kips} \]

CAPACITY
K = 1.0 (PIN-PIN CONNECTION)

TRY L110 x 33

\[ \phi P_{n} = 195 \text{ kips} > 7.84 \text{ kips} \checkmark \]

\[ f_{k} = 4.19 \text{ in} \quad , \quad y_{f} = 1.94 \text{ in} \]

STRONG AXIS

\[ \frac{K_{Lx}}{f_{x}} = \frac{(1)(17' x 12'')}{4.19''} = 49 \]

WEAK AXIS

\[ \frac{K_{Ly}}{f_{y}} = \frac{(1)(17' x 12'')}{1.94'} = 105 \quad \text{WEAK AXIS CONTROLS} \]

USE L110 x 33 COLUMN
COLUMN FOOTING DESIGN - F1

ASSUMPTIONS: EXPANSIVE CLAY SOIL
ALLOWABLE SOIL PRESSURE = 1.5 ksf

SERVICE LOADS: 
(14 psf + 20 psf) x 160 sf = 5,440 lbs = 6 kips

AREA REQUIRED = \( \frac{6 \text{kips}}{1.5 \text{ksf}} = 4 \text{sf} \)  \( L_{\min} = 2 \text{ft} \)

TRY 4' x 4' SQUARE FOOTING (A = 16 sf)

FACTORED LOADS: 
\[ 1.2(14 \text{ psf}) + 1.6(20 \text{ psf}) \] \times 160 \text{sf} = 8 \text{kips}

\[ q_s = \frac{8 \text{kips}}{16 \text{ft}^2} = 0.5 \text{ ksf} \]

DEPTH OF FOOTING

TRY 2' DEEP (4' x 2', d = 20"")  \( h_w = \)

\[ V_u = q_s \times \text{trib area} \]
trib area = \[ (4')^2 - \frac{(12'' + 20'')^2}{144} \] = 9 \text{ft}^2

\[ V_u = 0.5 \text{ ksf} \times 9 \text{ft}^2 = 4.5 \text{kips} \]

\[ V_c = 4.5 \frac{\text{ft}}{} \]

\[ \phi V_n = 0.75 V_c (h) d \]
\[ = 0.75 (4.5)(15000 \text{ psi})(4')(12'' + 20'') = 436 \text{kips} \]

\( dV_h = V_u \checkmark \)

TWO WAY ACTION

\[ V_u = 0.5 \text{ ksf} \times 4'(2' - 20'') = 6.70 \text{kips} \]

\[ \phi V_n = \phi \left( 2 \frac{\text{ft}^2}{\text{kips}} \right) \text{bw.d} \]
\[ = 0.76 \left( 2 \frac{5000}{(4')(12'')(20'')} \right) = 78 \text{kips} \]

\( \phi V_h = V_u \checkmark \)

78 kips > 6.7 kips \( \checkmark \)
FOOTING REINFORCEMENT

\[ f'c = 3,000 \text{ psi} \]
\[ f_t = 60 \text{ ksi} \]
\[ P_d = 8 \text{ kips} \]
\[ q_s = 0.5 \text{ ksf} \]

\[ M_u = 0.5 \text{ ksf} \times 4' \times \frac{(1.5')^2}{2} = 2.15 \text{ kip}\cdot\text{ft} \]

\[ A_{req} = \frac{M_u}{f_t f_y j d} = \frac{2.15 \text{ kip}\cdot\text{ft} \times 12''}{0.9(60 \text{ ksi})(0.95)(20'')} = 0.03 \text{ in}^2 \]

USE MINIMUM REINFORCEMENT

\[ A_{min} = \max \left\{ \frac{0.0014(40,000)}{40,000} (48'')(12') = 2.07 \text{ in}^2 \right\} \]

TRY (5) #6 \( (A_e = 2.20 \text{ in}^2) \)

\[ s_{max} = \min \left\{ \frac{18''}{5h = 120''} \right\} \]
\[ s_{max,\text{flex}} = \min \left\{ \frac{3h = 72''}{18''} \right\} \]
\[ s_{prov} = (4' \times 12'') - (2' \times 5'') - 5(0.75 \text{ in}) = 4 s_{prov} \]
\[ s_{prov} = 9.5'' \]

USE 5 #6 BARS EACH WAY
\[ A_e = 2.20 \text{ in}^2 \]
SOLVE FOR MOMENT CAPACITY

\[ C_0 = 0.002 \]

\[ e = \frac{0.85 \times 6}{12} = \frac{5(0.49 \text{ in}^2)(60 \text{ ksf})}{0.85 (5 \text{ ksi})(0.85)(48 \text{ in})} = 0.76 \text{ in} \]

\[ a = 0.36 (0.76^\circ) = 0.65 \text{ in} \]

\[ \varepsilon = \frac{0.002 (20'' - 0.76'')}{0.76''} = 0.076 \text{ in/in} = 0.0021 \text{ in/in} \]

STEEL YIELDS \( \checkmark \)

\[ \varepsilon = 0.004 \text{ in/in} \]

\[ M_n = 0.9 A_s f_y (d - \frac{a}{2}) \]

\[ = 0.9 (5)(0.49 \text{ in}^2)(60 \text{ ksf})(20'' - \frac{0.65''}{2}) \]

\[ = 195 \text{ kip-ft} \]

\[ l_d(f_y) = \frac{48'' - 10'' - 3''}{2} = 12'' \]

\[ l_d(\varepsilon) = \frac{60,000}{25 \times 3000} (0.75) = 32.9'' > 12'' \times \text{N.O.} \]

USE 90° STANDARD HOOKS

\[ \checkmark M_n \geq M_n \]

195 kip-ft \( \geq \) 225 kip-ft \( \checkmark \)
LATERAL KEY PLAN

REFERENCE

CALCULATIONS

Job  Virunga Coffee Co-op  Sheet No.  L1
Job No. 001  Date  5/20/18  Client  Journeyman Int.
Calculated By  CA  Checked By  AG
SHEAR WALL DESIGN - N/S SU1

\[ V_s = 14.0 \text{ kips} \]

\[ 7.0 \text{ kips} \]

\[ 17 \text{ kips} \]

\[ 5.3 \text{ kips} \]

53' - 0''
SHEAR WALL DESIGN - SH1

**ASSUMPTIONS:**
- RAMMED EARTH LIALL ($f_c' = 1500$ psi)
- HEIGHT = 12' - 0"
- SPAN = 20' - 0"
- LOAD RESISTANCE FACTOR DESIGN (LRFD)
  - SD5 = 0.1909

**LOADS:**
- $1.0 + 0.7 \cdot SD5 \cdot D + 0.5L + E$
- $0.9 - 0.2 \cdot SD5 \cdot D - E$
- $1.2 \cdot D + 0.5L + E$
  - 1.2 \cdot D + 0.5L + E = 0.862D - E$
- $0.9 - 0.2 \cdot (0.91) \cdot D - E$

**TRIB LUGHT OF LIALL = 5'**

- $w_{liall} = 1.24 \cdot (14.0 \text{ PSF})(6') + 0.5(20 \text{ PSF})(5') = 0.14 \text{ klf}$
- $w_{liall} = 0.862(14.0 \text{ PSF})(5') = 60.3 \text{ klf} = 0.06 \text{ klf}$
- $P_{wall} = 1.24 \cdot (125 \text{pcf})(12')(20')(12') = 37.2 \text{ kips}$
- $V_u = 5.5 \text{ kips}$

**SHEAR DESIGN**

- $h_u/h_w = 12'/20' = 0.60 \leq 1.0$ ✔️

- $h_u/h_w \leq 2.0$ ➤ $P_u \geq P_h$ ➤ TWO CURTAINS OF REINFORCING IS NOT REQUIRED

**ASSUME $\phi_v = 0.6$**

- $\phi V_u = \phi A_v \left( \alpha_c \frac{f_c'}{f_c} \right)$
  - $= 0.6 \cdot (20' \times 12') \cdot (3.0 \times 1.0) \cdot 1500$ psi
  - $= 16.75 \text{ kips} > V_u$

**USE MINIMUM REINFORCING**

- $P_v = 0.025 (12')(12') = 0.36 \text{ m}^2/ft$

**USE #4 E.F.**

- $A_v = 2(0.2 \text{ in}^2) = 0.4 \text{ in}^2$
  - $V_v = \frac{(0.2 \text{ in}^2)(60 \text{ ksf})(20' \times 12'')}{12} = 430 \text{ kips}$

- $\phi V_n = 304 \text{ kips}$

- $V_{n\max} = 0.1 A_n \sqrt{f_c} = 0.2 (12')(12') \cdot 1500$ psi = 892 kips > 304 kips ✔️
FLEXURAL DESIGN

Assume T = C = \( \frac{Mu}{0.9lw} = \frac{(5.3 \text{kips})(12')}{0.9(20')} = 4 \text{kips} \)

\( A_{req} = \frac{4 \text{kips}}{0.9(60 \text{ksi})} = 0.07 \text{ in}^2 \)

Try #4

\( \phi M_n = 4,136 \text{ kip-ft} \)

Depth = 31'

CHECK IF \( \phi = 0.6 \)

\( V_n = \frac{304 \text{kips}}{0.6} = 507 \text{kips} \)

\( M_{n, \text{max}} = 4,136 \text{ kip-ft}/0.9 = 4,595 \text{ kip-ft} \)

\( V_n \times h_{eff} = 507 \text{kips} \times 12' = 6,084 \text{kip-ft} > M_n \)

\( \therefore \phi = 0.75, \text{ wall will yield in flexure before shear} \)

\( \phi V_n = 507 \times 0.75 = 380 \text{kips} \)
BOUNDARY CONFINEMENT DESIGN

\[ \frac{f_w}{f_{yw}} = \frac{12}{20} = 0.60 < 2.0 \quad \therefore \text{USE 18.10.6.5} \]

\[ f_c = \frac{P_u}{A_{ov}} \pm \frac{M_u}{b_w l_w} \]

\[ f_c = \frac{400 \text{kips}}{(12'')(240''^2)} \pm \frac{64 \text{kip-ft} \times 12''}{(12'') (240'')^2} = 0.021 = 21 \text{ psi} \]

0.2f'_c = 0.2 \times (1500 \text{ psi}) = 300 \text{ psi} > f_c \quad \therefore \text{SPECIAL CONFINEMENT IS NOT REQUIRED}

0.15f'_c = 225 \text{ psi} > f_c

(a) Transverse ties shall be hoops
(b) Bends shall engage longitudinal bars
(c) 5" ties enclosing No.10 or smaller bars
(d) See above
(e) \( h_o = 14'' \)

\[ 400 \times \frac{1}{f_y} = 0.0067 \]

\[ f_{\text{boundary}} = \frac{A_s}{bd} = \frac{0.2 m^2}{12'' \times 12''} = 0.0014 < 0.0067 \quad \text{TRANSVERSE NOT REQUIRED} \]

VERTICAL SPACING

\[ s_{\text{min}} = 6'' = 6'' \]

\[ s_{\text{min}} = 6(0.5'') = 3'' \]

90° HOOKS SHALL BE USED

CONFINEMENT STEEL SHALL EXTEND 12'' INTO FOOTING UNTIL \( f_c \leq 1.5 f'_c \)
Code: ACI 318-14
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 05/22/18
Time: 10:42:12

File: c:\users\agupta\appdata\local\temp\sw #1.col
Project: Virunga SW #1

Column:
\[ f'c = 2 \text{ ksi} \quad f_y = 60 \text{ ksi} \quad E_c = 2208 \text{ ksi} \quad E_s = 29000 \text{ ksi} \quad f_c = 1.275 \text{ ksi} \quad e_{yt} = 0.00206897 \text{ in/in} \quad e_u = 0.003 \text{ in/in} \quad \beta_1 = 0.85 \quad \phi(a) = 0.8, \phi(b) = 0.9, \phi(c) = 0.65 \]

Engineer: CA
\[ A_g = 2880 \text{ in}^2 \quad A_s = 8.00 \text{ in}^2 \quad \rho = 0.28\% \quad I_x = 1.3824e+007 \text{ in}^4 \quad I_y = 34560 \text{ in}^4 \quad \text{Min clear spacing} = 7.23 \text{ in} \quad \text{Clear cover} = 0.75 \text{ in} \]
General Information:

File Name: c:\users\aggupta\appdata\local\temp\sw #1.col
Project: Virunga SW #1
Column: ACI 318-14
Units: English
Run Option: Investigation
Run Axis: X-axis
Slenderness: Not considered
Column Type: Structural

Material Properties:

Concrete: User-defined
\( f'c = 2 \text{ ksi} \)
\( E_c = 2207.6 \text{ ksi} \)
\( f_c = 1.275 \text{ ksi} \)
\( E_p = 0.003 \text{ in/in} \)
\( \beta_{c} = 0.85 \)

Steel: Standard
\( f_y = 60 \text{ ksi} \)
\( E_s = 29000 \text{ ksi} \)
\( \varepsilon_{y,t} = 0.002006897 \text{ in/in} \)

Section:

Rectangular:
Width = 12 in
Depth = 240 in

Gross section area, \( A_g = 2880 \text{ in}^2 \)

Ix = 1.3824e+007 \text{ in}^4
rx = 69.282 in
Xo = 0 in
Yo = 0 in

Reinforcement:

Bar Set: ASTM A615

Size Diam (in) Area (in^2) Size Diam (in) Area (in^2)
# 3 0.38 0.11 # 4 0.50 0.20 # 5 0.63 0.31
# 6 0.75 0.44 # 7 0.88 0.60 # 8 1.00 0.79
# 9 1.13 1.00 # 10 1.27 1.27 # 11 1.41 1.56
# 14 1.69 2.25 # 18 2.26 4.00

Confinement: Tied; #3 ties with #10 bars, #4 with larger bars.
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

Pattern: Irregular
Total steel area: \( A_s = 8.00 \text{ in}^2 \) at \( \rho = 0.28\% \) (Note: \( \rho < 0.50\% \))
Minimum clear spacing = 7.23 in

Factored Loads and Moments with Corresponding Capacities:

<table>
<thead>
<tr>
<th>No.</th>
<th>Pu</th>
<th>Mix</th>
<th>PhiMax</th>
<th>PhiMin</th>
<th>Mu</th>
<th>NA</th>
<th>Depth</th>
<th>Dt</th>
<th>depth</th>
<th>eps_t</th>
<th>Phi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>39.00</td>
<td>84.00</td>
<td>4135.51</td>
<td>49.232</td>
<td>31.02</td>
<td>233.00</td>
<td>0.01953</td>
<td>0.900</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*** End of output ***
SHEAR WALL DESIGN - E/W - SW2

DISTRIBUTION OF BASE SHEAR

\[ V = 14k \quad 38.5'-0'' \]

- \[ R_1 = 32'-0'' \]
- \[ R_2 = 45'-0'' \]
- \[ R_3 = 77'-0'' \]

\[ R_3 = 14k \left( \frac{45-38.5}{45} \right) = 2.02k \]

\[ R_2 = 14-2.02k = 11.98k = 12k \]

\[ R_1 = \frac{14k}{77'} = 0.18 \text{ k/ft} \left( \frac{32'}{12} \right) = 2.91k = 3k \]

\[ \rightarrow \text{DESIGN SUPPORT } R_1 \text{ AS SHEAR WALL SW2.} \]

SHEAR WALL SW2 DESIGN

- \[ L = 13'-0'' \]
- \[ H = 13'-0'' \text{ (MEAN)} \]

[ \[ h > 10'' : \text{USE 2 LAYERS OF REINF.} \]

\[ \text{MIN. WALL THICKNESS} \geq 4'' \]

\[ h = \frac{135 (13'x12)}{13} = 6.29'' \text{ (GOVERNS)} \]

\[ h = 12'' \text{ (>hmin = 6.29'')} \]

[ \[ w = 13' \]

\[ h = 12'' \]
LOAD COMBINATIONS

\[(1.2 + 0.2 \text{ psf}) D + 0.5 L + E = 1.240 + 0.5L + E\]
\[(0.9 - 0.2 \text{ psf}) D - E = 0.862D - E\]

LOADS

\[W_{\text{wall}} = 1.24 (14.0 \text{ psf})(1') + 0.5 (20 \text{ psf})(11') = 27.1 \text{ plf}\]

\[P_{\text{wall}} = 1.24 (125 \text{ pcf})(12''/12') (13')(13') = 26.2 \text{ kips}\]

\[P_{\text{beam}} = 1.24 (19.0 \text{ psf})(16'\times11.5') = 3.2 \text{ kips}\]

Assume beam is distributed along wall length: 3.2K/18' = 0.25 klf

\[\rightarrow W_{\text{wall total}} = 27.1 \text{ plf} + 250 \text{ plf} = 277.1 \text{ plf} = 277 \text{ plf}\]

SHEAR DESIGN

\[\frac{h_w}{f_w} = \frac{13'}{13'} = 1 \ (\leq 1.5) \checkmark\]

Assume \(\phi_v = 0.6\)

\[\phi V_c = \phi AC (962 \sqrt{FC})\]

\[= 0.6(13' \times 13')(3)(1.6) (\frac{4150}{1500})\]

\[= 11.8K \ (> V_u = 3K) \checkmark\]
USE MINIMUM REINFORCEMENT

\[ f_c = 0.0025 \text{ in}^2/\text{ft} \]

\[ \Rightarrow \text{USE #4 E.F. (AV = 2.0 in^2)} = 0.6 \text{ in}^2 \]

\[ V_S = \frac{(0.6 \text{ in}^2)(2)(60 \text{ kpsi})(13' \times 12'\text{ft})}{12} = 312 \text{ kips} \]

\[ \phi V_S = 0.6(312 \text{ k}) = 187.2 \text{ k} \]

\[ \phi V_n = \phi V_c + \phi V_S = 118.2 + 187.2 = 306 \text{ k} = 200 \text{ k} \]

\[ V_n \text{ max} = 8\sqrt{f_c} = 8(13')(12'\times 12') \frac{1500}{5200} = 580 \text{ k} \Rightarrow \phi V_n \text{ max} = 348 \text{ k} \]

\[ \phi V_n \text{ max} = 348 \text{ k} > \phi V_n = 200 \text{ k} \checkmark \]

:: USE #4 @ 12" E.F. (HORIZONTAL)

#4 @ 12" E.F. (VERTICAL)

FLEXURAL DESIGN

ASSUME \( T = C = \frac{M_u}{0.9 f_m} = \frac{(8)(13')}{0.9(12')} = 3.33 \text{ k} \)

\[ A_{\text{req}} = \frac{3.33 \text{ k}}{0.9(60 \text{ kpsi})} = 0.062 \text{ in}^2 \Rightarrow \text{TRY #4 BARS (As = 0.20 in}^2) \]

\[ (\#3 \text{ could be acceptable, but TRY #4 to be conservative}) \]

\[ \phi M_n = 1820 \text{ k}\cdot\text{ft} \]

VERIFY \( \phi = 0.6 \)

\[ V_n = \frac{200 \text{ k}}{0.6} = 333.3 \text{ k} \]

\[ V_n \text{ max} = 1820 \text{ k}\cdot\text{ft}/0.9 = 2022.2 \text{ k}\cdot\text{ft} \]

\[ V_n \times h_{\text{eff}} = 333.3 \text{ k}(13') = 4333 \text{ k}\cdot\text{ft} (> M_n \text{ max}) \]

\[ \therefore \phi = 0.75 \Rightarrow \text{wall will yield in flexure before shear} \]

\[ \Rightarrow \phi V_n = 0.75(333.3 \text{ k}) = 250 \text{ k} \]
BOUNDARY CONFINEMENT DESIGN

\[ \frac{h_w}{b_w} = \frac{13'11/16'}{13'} = 1.0 \left( \leq 2.0 \right) \therefore USE ACI 18.10.6.3 \]

\[ f_c = \frac{f_{cu}}{A_{ov}} \pm \frac{M_u}{b_n l_n \sqrt{6}} = \frac{30k}{(12'' \times 15'')} \pm \frac{(3k)(13') \times 12''}{(12'')(15'')^2 \sqrt{6}} = 0.026 = 26 \text{ psi} \]

0.2 \( f_{ec} = 0.2 \times 1500 \text{ psi} = 300 \text{ psi} \)  (\( > f_c \)) \therefore SPECIAL CONFINEMENT NOT REQ'D.

0.15 \( f_{ec} = 225 \text{ psi} \)  (\( > f_c \))

18.7.5.2

(a) TRANSVERSE TIES SHALL BE HOOPS
(b) BENDS SHALL ENGAGE LONGITUDINAL BARS
(c) NO.3 TIES ENCLOSING NO.10 OR SMALLER BARS
(d) SEE ABOVE
(e) \( f_{ty} = 14' \sqrt{\frac{400}{60,000}} = 0.005 \text{ psi} \)

\[ \phi \text{ BOUNDARY } = \frac{A_s}{bd} = \frac{0.2 \text{ in}^2}{(12'')(12'')} = 0.0014 \quad (\leq 0.005 \text{ psi}) \therefore TRANSVERSE REINF. NOT REQ'D \]

VERTICAL SPACING

\[ S_{max} = \text{MIN. } \left\{ \begin{array}{c} 6'' \rightarrow 6'' \vspace{0.5cm} 6db = 6(0.5'') = 3'' \text{ GOVERNS} \end{array} \right. \]

* STANDARD 90° HOOKS SHALL BE USED

* CONFINEMENT STEEL SHALL EXTEND 12'' INTO FORMING UNTIL \( f_c = 1.5 \times f_{ec} \)
Code: ACI 318-14
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 05/22/18
Time: 10:42:39

File: u:\senior project\shear wall sw2.col

Project:
Column:
\( f'c = 2 \text{ ksi} \)  \( f_y = 60 \text{ ksi} \)
\( E_c = 2549 \text{ ksi} \)  \( E_s = 29000 \text{ ksi} \)
\( f_c = 1.7 \text{ ksi} \)  \( e_{yt} = 0.00206897 \text{ in/in} \)
\( e_{u} = 0.003 \text{ in/in} \)
\( \beta_1 = 0.85 \)
Confinement: Tied
\( \phi(a) = 0.8, \phi(b) = 0.9, \phi(c) = 0.65 \)

Engineer:
\( A_g = 1872 \text{ in}^2 \)  \( 28 \#4 \text{ bars} \)
\( A_s = 5.60 \text{ in}^2 \)  \( \rho = 0.30\% \)
\( I_x = 3.79642e+006 \text{ in}^4 \)
\( I_y = 22464 \text{ in}^4 \)
\( \text{Min clear spacing} = 7.25 \text{ in} \)  \( \text{Clear cover} = 1.87 \text{ in} \)
General Information:
=================================
File Name: u:\senior project\shear wall sw2.col
Project: Column:
Code: ACI 318-14
Run Option: Investigation
Run Axis: X-axis
Engineer: Slenderness: Not considered
Units: English
Column Type: Structural

Material Properties:
=================================
Concrete: Standard
f'c = 2 ksi
Ec = 2549.12 ksi
fc = 1.7 ksi

Steel: Standard
fy = 60 ksi
Es = 29000 ksi
Eps_yt = 0.00206897 in/in
Beta_l = 0.85

Section:
=================================
Rectangular: Width = 12 in
Depth = 156 in
Gross section area, Ag = 1872 in^2
Ix = 3.79642e+006 in^4
rx = 45.033 in
xo = 0 in

ry = 22464 in^4
Yo = 0 in

Reinforcement:
=================================
Bar Set: ASTM A615

<table>
<thead>
<tr>
<th>Size Diam (in)</th>
<th>Area (in^2)</th>
<th>Size Diam (in)</th>
<th>Area (in^2)</th>
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</thead>
<tbody>
<tr>
<td># 3</td>
<td>0.38</td>
<td># 4</td>
<td>0.50</td>
</tr>
<tr>
<td># 6</td>
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<td>0.88</td>
</tr>
<tr>
<td># 9</td>
<td>1.13</td>
<td># 10</td>
<td>1.27</td>
</tr>
<tr>
<td># 14</td>
<td>1.69</td>
<td># 18</td>
<td>2.26</td>
</tr>
</tbody>
</table>

Confinement: Tied; #3 ties with #10 bars, #4 with larger bars.
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

Layout: Rectangular
Pattern: Equal Bar Spacing (Cover to transverse reinforcement)
Total steel area: As = 5.60 in^2 at rho = 0.30% (Note: rho < 0.50%)
Minimum clear spacing = 7.25 in

28 #4 Cover = 1.5 in

Factored Loads and Moments with Corresponding Capacities:
=====================================================================
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<thead>
<tr>
<th>No.</th>
<th>Pu</th>
<th>Mux</th>
<th>PhiMnx</th>
<th>PhiMn/Mu</th>
<th>NA Depth</th>
<th>Dt Depth</th>
<th>eps_t</th>
<th>Phi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>0.00</td>
<td>1819.95</td>
<td>999.999</td>
<td>15.23</td>
<td>153.88</td>
<td>0.02731</td>
<td>0.900</td>
</tr>
</tbody>
</table>

*** End of output ***
**Shear Wall Foundation - N/S E2**

\[ V_e = 5.3 \text{ kips} \]
\[ P_{BL} = 39 \text{ kips} \]
\[ P_L = 1 \text{ kip} \]

**Service Load Combinations**

5) \((1.0 + 0.14 \text{ SD})D + 0.7E\)
6) \((1.0 + 0.103 \text{ SD})D + 0.75L + 0.52BE\)
8) \(0.6D + 0.7E \Rightarrow \text{SDS not req'd}\)

Combine 5) & 6): \((1.0 + 0.14 \text{ SD})D + 0.75L + 0.7E\)

**Overturning Moment**

\[ M_{ot} = (0.75)(0.7)(5.5 \text{ kips})(12') = 39 \text{ kip-ft} \]

Try \(L = 26', H = 6', t = 3'\)

**Load Case 1: 0.6D + 0.7E**

\[ P_{BL} = 39 \text{ kips} \]
\[ P_{FG} = (0.13 \text{ ksf})(26')(6')(3') = 71 \text{ kips} \]
\[ E_P = 39 \text{ kips} + 71 \text{ kips} = 110 \text{ kips} \times 0.6 = 66 \text{ kips} \]
\[ M_{Resist} = 66 \text{ kips} \times (26'/2) = 888 \text{ kip-ft} \geq 39 \text{ kip-ft} \checkmark \]
\[ x = \frac{M_{Resist} - M_{ot}}{2P} = \frac{888 \text{ kip-ft} - 39 \text{ kip-ft}}{66 \text{ kips}} = 12.48 \text{ ft} \]
\[ l = 3x = 37 \text{ ft} \]
\[ f_{bearing} = \frac{66 \text{ kips}}{(\frac{1}{2})(37')(6')} = 0.6 \text{ ksf} \]
\[ f_{allow} = 1.5 \text{ ksf} \times 1.32 = 2.0 \text{ ksf} \]

**Fallout & Forces**

\[ 2.0 \text{ ksf} \geq 0.6 \text{ ksf} \checkmark \]
LOAD CASE II: \((1.0 + 0.14 \text{SPS})D + 0.76L + 0.7E\)

\[ P_{DL} = 59 \text{ kips} \]
\[ P_L = 1 \text{ kip} \]
\[ P_{Ft} = 71 \text{ kips} \]

\[ \varepsilon P = \left(1.0 + 0.14(0.19)\right)(39 \text{ kips} + 71 \text{ kips}) + 0.75(1 \text{ kip}) = 114 \text{ kips} \]

\[ M_{res} = 114 \text{ kips} \times \left(\frac{26'}{2}\right) = 1,482 \text{ kip-ft} \geq 34 \text{ kip-ft} \checkmark \]

\[ x = \frac{1,482 \text{ kip-ft} - 34 \text{ kip-ft}}{114 \text{ kips}} = 12.7 \text{ ft} \]

\[ l = 37 \text{ ft} \]

\[ f_{bgr} = \frac{114 \text{ kips}}{\frac{1}{2}(37')(6')} = 1.02 \text{ ksf} \]

\[ f_{allow} = 2.0 \text{ ksf} \]

FACTORED LOAD DESIGN

5) \((1.2 + 0.2 \text{SPS})D + 0.5L + E\)

7) \(0.9D + E\)

USE LC # 5

\[ P = (1.2 + 0.2(0.19))(110 \text{ kips}) + 0.5(1 \text{ kip}) = 137 \text{ kips} \]

ASSUME \(d = 2.67'\)

\[ \frac{1.24 \text{ ksf}}{37 \text{ ft}} = \frac{x}{37' - 23' - 2.67'} \]

\[ x = 0.9 \text{ ksf} \]

\[ V_0 = \left(\frac{0.9}{0.6}\right)\left[\frac{1}{2}(\frac{1}{4})(124 - 0.4) + 0.4 \text{ ksf} \times \frac{1}{2}\right](6') = 2.96 \text{ kips} \]

\[ \phi V_0 = 0.75(2) \left\{ 1500 \text{ psi} \times \frac{6''}{12''} \times (2.67') \times \frac{12''}{12''} \right\} = 134 \text{ kips} \]

\[ \phi V_0 \geq V_0 \checkmark \]

\[ 134 \text{ kips} \geq 2.96 \text{ kips} \checkmark \]
LONGITUDINAL BTM REINFORCEMENT

\[ q = 124 \text{ kbf} \]
\[ V_1 = \frac{0.4}{0.6} (0.5)(1.24 \text{ ksf} - 0.4 \text{ ksf})(3')(6') = 11.34 \text{ kips} \]
\[ V_2 = \frac{0.4}{0.6} (0.4 \text{ ksf})(3')(6') = 10.8 \text{ kips} \]
\[ \beta_1 = \frac{2}{3}(3') = 2' \]
\[ \beta_2 = 1.5' \]
\[ \Sigma M_u = 11.34 \text{ kips}(2') + 10.8 \text{ kips}(1.5') \]
\[ = 39 \text{ KIP-FT} \]

\[ A_{min} = 0.001811 + = 4.67 \text{ in}^2 \]

TRY (8) # 5 (8) LONG
\[ \Gamma = 8(0.81 \text{ in}^2)(60 \text{ ksi}) = 149 \text{ KIPS} \]

\[ \alpha = \frac{149 \text{ kips}}{0.85(15 \text{ ksi})(6' x 12''}) = 1.62'' \]
\[ \phi = 1.91'' \]
\[ E_2 = \frac{0.003(2.67' x 12'' - 1.91'')}{1.91''} = 0.097''/\text{in} > 0.0021''/\text{in} \text{ STEEL YIELDS} \]
\[ \phi = 0.9 \]
\[ \phi M_n = 0.9 (3)(0.81 \text{ in}^2)(60 \text{ ksi})(31'' - \frac{1.62''}{2}) \div 12 = 837 \text{ KIP FT} \]
\[ 337 \text{ KIP-FT} < 39 \text{ KIP-FT} \]

\[ (8) \# 5 \text{ LONG. (B)} \]
TRANSVERSE FLEXURAL REINFORCEMENT (BTM)

\[ W_u = (0.9/0.6) (1.24 \text{ ksf}) = 1.86 \text{ ksf} \]

\[ M_u = 1.86 \text{ ksf} \times (2.5')^2 / 2 = 6 \text{ kip-ft/ft} \]

\[ A_{\text{min}} = \frac{0.001 \beta (3' \times 12')(26' \times 12')}{2} = 10.1 \text{ in}^2 \]

**TRY #7 @ 16" 0.6 (A_s = 11.4 \text{ in}^2)\]

\[ a = \frac{(11.4 \text{ in}^2)(60 \text{ ksi})}{0.85(1.6 \text{ ksf})(26' \times 12')} = 1.72" \quad c = 2.02" \]

\[ E_s = 0.044 \text{ m/m} \quad \phi = 0.9 \]

\[ \phi M_u = 0.9 (0.6 \text{ m}^2)(60 \text{ ksi})(36" - 3" - 2" - \frac{1.72"}{2}) / 16 = 61 \text{ kip-ft/ft} \]

#7 @ 16" TRANSV (B)

LONGITUDINAL TOP REINFORCEMENT

\[ W_u = 1.4 (3')(1' \times 0.15 \text{ ksf}) = 0.63 \text{ ksf} \]

\[ M_u = 0.63 \text{ ksf} (3')^2 / 2 \times 6' = 17 \text{ kip-ft} \]

\[ A_{\text{min}} = 4.67 \text{ in}^2 \]

\[ A_{\text{min}}(\text{Top}) = \frac{4.67 \text{ in}^2}{2} = 2.34 \text{ in}^2 \Rightarrow (8) \#5 \text{ MIN } A_s = 2.48 \text{ in}^2 \]

\[ a = \frac{8(0.31 \text{ in}^2)(60 \text{ ksi})}{0.85(1.5 \text{ ksf})(6' \times 12')} = 1.62" \quad c = 1.91" \]

\[ E_s = 0.047 \text{ m/m} \quad \phi = 0.9 \]

\[ \phi M_u = 0.9 (0.31 \text{ in}^2)(60 \text{ ksi})(36" - 3" - 2" - \frac{1.62"}{2}) / 12 = 337 \text{ kip-ft} \]

TRANSVERSE TOP REINF.

\[ W_u = 0.63 \text{ ksf} \]

\[ M_u = 0.63 \text{ ksf} (2.5')^2 / 2 = 1.97 \text{ kip-ft/ft} \]

USE #7 @ 16" 0.6 (A_s = 11.4 \text{ in}^2)\]

\[ \phi M_u = 61 \text{ kip-ft/ft} \]

#7 @ 16" TRANSV (F)

\[ \phi M_u = M_u \checkmark \]

337 kip-ft 2 17 kip-ft

\[ (8) \#5 \text{ LONG. (T)} \]

\[ \phi M_u = M_u \checkmark \]

61 kip-ft/ft 2 1.77 kip-ft/ft

#7 @ 16" TRANSV (F)
SHEAR WALL FOUNDATION - E/W F3

\[ V_e = 3 \text{kips} \quad (V) \]
\[ P_{DL} = 29 \text{kips} \quad (P) \]
\[ P_{LL} = 1 \text{kip} \]

\[ 13' \]

\[ P \downarrow \]

\[ 13' \]

\[ L \]

\[ t \]

**Service Load Combinations**

5) \( (1.0 + 0.14 \cdot 505)0 + 0.7E \)
66) \( (1.0 + 0.10 \cdot 505)0 + 0.75L + 0.575E \)
8) \( 0.60 + 0.7E \rightarrow 505 \text{ NOT REBIAL} \)

\[ \rightarrow \text{COMBINE 5&66:} \quad (1.0 + 0.14 \cdot 505)0 + 0.75L + 0.7E \]

**Overturning Moment**

\[ M_{OT} = 0.75 \cdot (3)(9)(13') = 21 \text{kip-ft} \]

\[ \rightarrow \text{TRY} \quad L = 16', \quad W = 4', \quad t = 3' \]

**Load Case I: 0.60 + 0.7E**

\[ P_{DL} = 29 \text{kips} \]
\[ P_{F Ig} = (0.150 \text{KCF})(16')(4')(3') = 28.8 \text{k} \]
\[ E_P = 29 \text{k} + 29 \text{k} = 58 \text{k} \times 0.6 = 35 \text{k} \]
\[ M_{RESIST} = 35 \text{k} \cdot (16'/2) = 280 \text{ k-ft} \geq 21 \text{ k-ft} \checkmark \]
\[ X = \frac{M_{RESIST} - M_{OT}}{2P} = \frac{280 - 21}{35} = 7.4' \]
\[ l = 3X = 3(7.4') = 22.2' \]
\[ f_{BEARING} = 35 \text{k} / (2)(22.2')(4') = 0.79 \text{ ksf} \]
\[ f_{ALLOW} = 1.5 \text{ksf} \times 1.33 = 2.0 \text{ ksf} \text{ (33% INCREASE ALLOWED)} \]
LOAD CASE II: \((1.0 + 0.14 \cdot 0.05) D + 0.75L + 0.76\)

- **PDL**: 29 kips
- **PIL**: 1 kip
- **PFG**: 29 kips

\[
\begin{align*}
\delta P &= (1 + 0.14(0.19))(29 + 29) + 0.75 \cdot (1) = 60.3 \text{ k}
\end{align*}
\]

- **MRESIST**: 60.3 k (16/12) = 482.4 k-ft (> 21 k-ft) ✓

\[
\begin{align*}
\chi &= \frac{482.4 \text{ k-ft} - 21 \text{ k-ft}}{60.3} = 7.65' = 7.71'
\end{align*}
\]

\[
\begin{align*}
x &= 3 \chi = 3(7.71') = 23.1'
\end{align*}
\]

- **fBEARING**: 60.3 / (1/2 \times 23.1' \times 1') = 1.30 ksf

- **fALLOW**: 2.0 ksf ✓

**FACTORED LOAD DESIGN**

5) \((1.2 + 0.2 \cdot 0.05) D + 0.5L + E\)

7) 0.9D + E

**LC #5**: \(P = (1.2 + 0.2(0.19))(58k) + 0.5(1k) = 72.3k\)

* **ASSUME** \(d = 2.67'\)

\[
\begin{align*}
\frac{1.30 \text{ ksf}}{23.1'} &= \frac{x}{23.1' - 0.33'}
\end{align*}
\]

\[
\begin{align*}
\Rightarrow \chi &= 1.27 \text{ ksf}
\end{align*}
\]

\[
\begin{align*}
V_U &= \left(\frac{0.9}{0.6}\right) \left[\frac{1}{2}(0.33')(1.30-1.27) + 1.27'(0.33')\right] 4' = 2.57 \text{ k}
\end{align*}
\]

\[
\begin{align*}
\phi_{VC} &= 0.75(2)1500 \cdot (4 \times 12')(2.67')(12')
\end{align*}
\]

\[
\begin{align*}
\Rightarrow \phi_{VC} &= 89.3 \text{ k} (> V_U = 2.57 \text{ k}) ✓
\end{align*}
\]
LONGITUDINAL BOTTOM REINFORCEMENT

\[ q = 1.27 \text{ ksf} \]

\[ V_1 = \left( \frac{0.9}{0.6} \right) (0.5) (1.30 - 1.27) (3') (4') = 11.43 \text{ k} \]

\[ V_2 = \left( \frac{0.9}{0.6} \right) (1.27 \text{ ksf}) (3') (4') = 10.91 \text{ k} \]

\[ l_1 = 2/3' = 2' \]

\[ l_2 = 1.5' \]

\[ EMu = 11.43 \text{ k} (2') + 10.91 \text{ k} (1.5') = 32.2 \text{ k-ft} \]

\[ ASmin = 0.0018 A_g = 0.0018(4\times12)(3\times12) = 3.11 \text{ in}^2 \quad (\text{SLIT TOP & BOTTOM}) \]

TRY (6) #5 (BOTTOM LONG.)

\[ 7 = 6(0.31 \text{ in}^2)(60 \text{ kpsi}) = 112 \text{ k} \]

\[ a = \frac{112 \text{ k}}{0.85 (1.5\text{kpsi})(4\times12)} = 1.83" \]

\[ c = 2.15" \quad \left( \frac{a}{\beta_1} \right) \rightarrow \beta_1 = 0.85 \]

\[ E_s = 0.003 \left( 2.67 \times 12" - 2.15" \right) = 0.0917 \text{ in/min} \left( > 0.0421 \right) \checkmark \text{STEEL YIELDS} \]

\[ \phi Mu = \left[ 0.9(6)(0.31 \text{ in}^2)(60 \text{ kpsi}) \left( 32" - \frac{1.83}{2} \right) \right] / 12 = 200.2 \text{ k-ft} \left( > Mu = 39.2 \text{ k-ft} \right) \checkmark \]

\[ \therefore \text{USE (6) #5 BARS LONG. (B)} \]

TRANSVERSE FLEXURAL REINFORCEMENT (BTM).

\[ W_u = \left( \frac{0.9}{0.6} \right) (1.27 \text{ ksf}) = 1.9 \text{ ksf} \]

\[ Mu = 1.9 \text{ ksf} (2.67')^2 / 2 = 6.7 \text{ k-ft/ft} \]

\[ ASmin = 0.0018 \left( 3 \times 12" \right) \left( 16 \times 12" \right) / 2 = 6.22 \text{ in}^2 \]

TRY #6 @ 12" o.c (AS = 7.84 in²)

\[ a = \frac{7.84 (60 \text{ ksi})}{0.85 (1.5\text{ksi})(16\times12)} = 1.72" \rightarrow c = 2.03" \]
\[ E_5 = 0.041 \text{ in/min (}> 0.0021) \checkmark \quad \phi = 0.9 \checkmark \]

\[ \phi M_n = 0.9 \left(0.44 \text{ in}^2\right) \left(60 \text{ ksi}\right) \left(36^\circ - 3^\circ - 2^\circ - \frac{1.72^\circ}{2}\right) / 12 = 59.7 \text{ k-ft/ft} \]

\[ (> 6.7 \text{ k-ft/ft}) \checkmark \]

\[ \therefore \text{USE #6 @ 12\textdegree o.c. TRANS. BOTTOM REINF.} \]

**LONGITUDINAL TOP REINFORCEMENT**

\[ W_n = 1.4 (3')(1') (0.15 \text{ ksf}) = 0.63 \text{ ksf} \]

\[ M_{u} = 0.63 \text{ ksf} (3')^2 / 2 \times 4' = 11.34 \text{ k-ft} \]

\[ A_{\text{VMIN}} = 3.11 \text{ in}^2 \]

\[ A_{\text{VMIN (TOP)}} = 3.11 \text{ in}^2 / 2 = 1.56 \text{ in}^2 \rightarrow \text{TRY (6) #5 (A_s = 1.86 \text{ in}^2)} \]

\[ a = \frac{6 (0.31) (60 \text{ ksi})}{0.85 (1.5 \text{ ksi}) (4 \times 2)} = 1.82'' \rightarrow c = 2.15'' \]

\[ E_5 = 0.0401 (> 0.0021) \checkmark \quad \phi = 0.9 \checkmark \]

\[ \phi M_n = 0.9 (6)(0.31) (60) (36^\circ - 3^\circ - 2^\circ - \frac{1.82^\circ}{2}) / 12 = 851.8 \text{ k-ft} (> 11.34 \text{ k-ft}) \checkmark \]

\[ \therefore \text{USE (6) #5 LONG. (7) REINFORCEMENT} \]

**TRANSVERSE TOP REINFORCEMENT**

\[ W_n = 0.63 \text{ ksf} \]

\[ M_{u} = 0.63 \text{ ksf} (2.67')^2 / 2 = 2.25 \text{ k-ft/ft} \]

\[ \text{TRY #6 @ 12\textdegree o.c. (A_s = 7.04 \text{ in}^2)} \]

\[ \phi M_n = 59.7 \text{ k-ft/ft} (> M_u = 2.25 \text{ k-ft/ft}) \checkmark \]

\[ \therefore \text{USE #6 @ 12\textdegree o.c. TRANS. TOP REINF.} \]
DIAPHRAGM DESIGN - N/S

\[ \omega = \frac{V_1}{g} = \frac{14k}{53'} \]

\[ \Rightarrow \omega = 0.264 \text{ klf} \]

ASPECT RATIO:

\[ 77'/53' = 1.45 \]

\[ \Rightarrow 1.45 \geq 3:1 \checkmark \]
**SHEAR DESIGN**

3/8" SHEATHING - STRUC 1 (UNBLOCKED)
ASSUME 8d NAILS

\[ V = 0.7V_u = 0.7(91 \text{ plf}) = 63.7 \text{ plf} \]

TRY 8d @ 6", 6", 12", NO BLKG, CASE 3

\[ V_{allow} = \frac{360}{2} = 180 \text{ plf} \]

\[ V_{allow} = 180 \text{ plf} > 63.7 \text{ plf} \checkmark \]

\[ \therefore 8d @ 6", 6", 12", NO BLOCKING \]

**CHORD FORCES**

\[ T/C CHORD = 688 \# (0.7) = 482\# \]

**COLLECTOR FORCES**

**INTERIOR COLLECTOR:**

\[ T = 91 \text{ plf} \]

\[ S = \frac{195}{135} \text{ plf} \]

\[ V = 135 \text{ plf} \]

\[ T/C MAX = 2912 \# \]
EXTERIOR COLLECTOR:

\[ V = 49 \text{ plf} \]

\[ V = 205 \text{ plf} \]

20' \quad \quad 57'

\[ T/C \text{ MAX} = 3920 \text{ #} \]

* COLLECTOR FORCES GOVERN
DEFLECTION - ASPECT RATIO

58'/77' = 0.69:1.0 < 3:1 √

SHEAR DESIGN

TRY 3/8" SHEATHING, STRUCTURAL 1 (UNBLOCKED), 8d NAILS

\[ V_u = 0.7 V_{max} = 0.7 \times (131 \text{ PLF}) = 92.0 \text{ PLF} \]

TRY 8d @ 6", 6", 12" NO BLOCKING, CASE 1

\[ V_{ABD} = 480 \text{ PLF} \]

\[ V_{ALLOW} = \frac{480 \text{ PLF}}{2} = 240 \text{ PLF} \]

\[ V_{ALLOW} \geq V_u \rightarrow 240 \text{ PLF} \geq 92 \text{ PLF} \checkmark \]

CHORD FORCE = 0.7(368 lbs) = 608 lbs

COLLECTOR FORCES

LINE E: \[ V = 131 \text{ PLF} \]

\[ V = 174 \text{ PLF} \]

USE 3/8" STRUC 1, 8d @ 6", 6", 12" NO BLOCKING REQUIRED
**REFERENCE**

**CALCULATIONS**

**LINE A:**

\[ 54 \text{ PLF} = y \]

\[ y = 220 \text{ PLF} \]

\[ 40' - 0'' \]

\[ 13' - 0'' \]

\[ +t \]

\[ -c \]

\[ 2160^* \]

**LINE B:**

\[ 77 \text{ PLF} \]

\[ 146 \text{ PLF} \]

\[ 19' - 0'' \]

\[ 28' - 0'' \]

\[ 6' - 0'' \]

\[ +t \]

\[ -c \]

\[ 1463^* \]

**COLLECTOR FORCE GOVERNS**

\[ P = 2160^* \]
CONCRETE BOND BEAM DESIGN

ASSUMED SECTION

**SECTION WILL BE PLACED HORIZONTALLY.**

\[ \begin{align*}
 f'c & = 1,000 \text{ psi} \\
 f_y & = 60 \text{ ksi} \\
 A_s & = 2 \text{ in}^2 \\
 M_u & = 53 \text{ k-ft}
\end{align*} \]

\[ a = d - \sqrt{\frac{-2M_u}{f_y} + d^2} \]
\[ d = 10" - 1.5" - 0.375" = 10" \text{ COVER STIRRUPS} \]

\[ a = 10" - \sqrt{\frac{-2(53\times12)}{(0.75)0.85(4)(8)} + 10^2} \]

\[ a = 3.86" \Rightarrow A_s = \frac{0.85f'cA_d}{f_y} = \frac{0.85(4)(8)(3.86)}{60} = 1.75 \text{ in}^2 \]

\[ \therefore \text{ USE (2) #9 REBAR T/R} \Rightarrow 2(1.00\text{in}^2) = 2 \text{in}^2 (> 1.75\text{in}^2) \]

FLEXURAL DESIGN

(\text{ASSUME} \ f_s = \ f_y)

\[ T = A_s f_y = (2)(60) = 120 \text{ k} = 0.85 f'c A_d = 0.85(4)(8) \text{ k} \Rightarrow a = 4.41" \]

\[ C = \frac{a}{0.85} = 4.11" \Rightarrow 5.19" \]

\[ e_s = \frac{0.003(10" - 5.19")}{5.19"} = 0.0028 \text{ (} e_y = 0.00207\text{)} \checkmark \text{ STEEL YIELDS} \]
\[ M_n = T (d - 0.8) = 120 \times (10 - 4.1) / 2 = 935.4 \text{ k}'' = 78 \text{ k}' \]

\[ \phi M_n = (0.75)(78 \text{ k}') = 58.5 \text{ k}' \quad (> 53 \text{ k-Fr}) \checkmark \text{ O.K.} \]
Code: ACI 318-14
Units: English
Run axis: About X-axis
Run option: Investigation
Slenderness: Not considered
Column type: Structural
Bars: ASTM A615
Date: 06/03/18
Time: 19:59:13

File: U:\SENIOR PROJECT\Bond Beam.col
Project:
Column:
f'c = 4 ksi  fy = 60 ksi
Ec = 3605 ksi  Es = 29000 ksi
fc = 3.4 ksi  e_yt = 0.00206897 in/in
e_u = 0.003 in/in
Beta1 = 0.85
Confinement: Tied
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

Engineer:
Ag = 96 in^2  4 #9 bars
As = 4.00 in^2  rho = 4.17%
Xo = 0.00 in  lx = 1152 in^4
Yo = 0.00 in  ly = 512 in^4
Min clear spacing = 3.49 in  Clear cover = 1.12 in
General Information:

File Name: U:\SENIOR PROJECT\Bond Beam.col

Project:
Column: ACI 318-14
Run Option: Investigation
Run Axis: X-axis

Material Properties:

Concrete: Standard
f'c = 4 ksi
Ec = 3605 ksi
fc = 3.4 ksi
Eps_u = 0.003 in/in
Beta1 = 0.85

Steel: Standard
f = 60 ksi
E = 29000 ksi

Section:
Rectangular: Width = 8 in Depth = 12 in

Gross section area, Ag = 96 in^2
Ix = 1152 in^4
rx = 3.4641 in

Reinforcement:
Bar Set: ASTM A615
Size Diam (in) Area (in^2) Size Diam (in) Area (in^2) Size Diam (in) Area (in^2)
# 3 0.38 0.11 # 4 0.50 0.20 # 5 0.63 0.31
# 6 0.75 0.44 # 7 0.88 0.60 # 8 1.00 0.79
# 9 1.13 1.00 # 10 1.27 1.27 # 11 1.41 1.56
# 14 1.69 2.25 # 18 2.26 4.00

Confinement: Tied; #3 ties with #10 bars, #4 with larger bars.
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

Layout: Rectangular
Pattern: Sides Different (Cover to transverse reinforcement)

Total steel area: A_s = 4.00 in^2 at rho = 4.17%
Minimum clear spacing = 3.49 in

Factored Loads and Moments with Corresponding Capacities:

Pu Mux PhiM/sx PhiM/sx NA Df depth eps_t Phi
No. kip k-ft k-ft in in
1 3.92 53.00 81.48 1.537 2.76 10.31 0.00822 0.900

*** End of output ***
**SLAB ON GRADE - N/S SLIDING CHECK**

\[
V_E \text{ (Service)} = 5.3 \text{kips} \times 0.7 = 4.0 \text{kips}
\]

\[
\sum P_{DL} = 66 \text{kips}
\]

Friction = \( \mu P_{DL} = 0.3(66 \text{kips}) = 20 \text{kips} \)

Passive = \( \frac{0.100 \text{KCF}(1.5')^2(6')}{2} = 4 \text{kips} \)

\[
\sum \text{Friction} + \text{Passive} = 24 \text{kips} > 4.0 \text{kips} \checkmark
\]

No dowels required

Also greater than max \( V_E \) in direction \( 0.7(7 \text{kips}) = 5.0 \text{kips} \) \checkmark
**SLAB ON GRADE - E/W SLIDING CHECK**

\[ V_E \text{ (service)} = 2.1 \text{ KIPS} \]

\[ \varepsilon_{PD} = 35 \text{ KIPS} \]

\[ \text{Friction} = 0.3 \times (35 \text{ KIPS}) = 10.5 \text{ KIPS} \]

\[ \text{Passive} = \frac{(0.100 \text{ Kc}) \times (1.38) \times (3')^2 \times (4')}{2} = 2.4 \text{ KIPS} \]

\[ \varepsilon_{\text{Friction}} + \varepsilon_{\text{Passive}} = 12.9 \text{ KIPS} > 2.1 \text{ KIPS} \checkmark \]

\* Also greater than max \( V_E \) in direction \( 0.7 \times (12 \text{ KIPS}) = 8.4 \text{ KIPS} \checkmark \]

No doublers required
Appendix B - Drawings
SENIOR PROJECT THESIS

VIRUNGA COFFEE//COCOA CO-OP
RWANDA, AFRICA

JOURNEYMAN INTERNATIONAL ENGINEERING TEAM
CALEB AZEVEDO | ANUGRAH GUPTA

DR. ALLEN ESTES

SPRING QUARTER 2018
CALIFORNIA POLYTECHNIC STATE UNIVERSITY
SAN LUIS OBISPO, CA

NOTE: NOT FOR CONSTRUCTION. TO BE REVIEWED AND APPROVED BY IN-COUNTRY ENGINEER.

SHEET INDEX
S0.1 - TITLE SHEET & SHEET INDEX
S1.1 - GENERAL NOTES
S2.1 - TYPICAL DETAILS
S2.2 - TYPICAL DETAILS
S2.3 - TYPICAL DETAILS
S2.4 - NORTH-SOUTH SHEAR WALL TYPICAL DETAILS
S2.5 - EAST-WEST SHEAR WALL TYPICAL DETAILS
S3.1 - FOUNDATION PLAN
S3.2 - ROOF FRAMING PLAN
4. Structural Steel: All structural steel shall conform to the following:
   a. Structural Framing:
      - All framing shall meet the requirements of ACI 301.
      - All framing shall be designed by a registered structural engineer.
      - All framing shall be fabricated and field-stress relieved.
      - All framing shall be installed in accordance with the fabricator's instructions.
   b. Structural Concrete:
      - All structural concrete shall meet the requirements of ACI 318.
      - All structural concrete shall be designed by a registered structural engineer.
      - All structural concrete shall be placed in accordance with the fabricator's instructions.

5. Miscellaneous:
   a. Site Preparation:
      - Site preparation shall be performed in accordance with the site preparation plans.
      - Site preparation shall be performed by a registered site preparation contractor.
   b. Materials:
      - All materials shall be in accordance with the material specifications.
      - All materials shall be approved by the project engineer.
   c. Quality Control:
      - Quality control shall be performed in accordance with the quality control plans.
      - Quality control shall be performed by a registered quality control auditor.
   d. Records:
      - Records shall be maintained in accordance with the record retention plans.
      - Records shall be maintained by a registered records manager.

6. Basis of Design:
   a. The structural design was prepared by a registered structural engineer.
   b. The structural design was reviewed and approved by the project engineer.
   c. The structural design was in accordance with the project specifications.
   d. The structural design was completed in accordance with the project schedule.

7. Construction:
   a. Construction shall be performed in accordance with the construction plans.
   b. Construction shall be performed by a registered construction contractor.
   c. Construction shall be performed in accordance with the construction specifications.
   d. Construction shall be performed in accordance with the construction quality control plans.

8. Site Preparation:
   a. Site preparation shall be performed in accordance with the site preparation plans.
   b. Site preparation shall be performed by a registered site preparation contractor.
   c. Site preparation shall be performed in accordance with the site preparation specifications.
   d. Site preparation shall be performed in accordance with the site preparation quality control plans.

9. Materials:
   a. Materials shall be in accordance with the material specifications.
   b. Materials shall be approved by the project engineer.
   c. Materials shall be fabricated and field-stress relieved.
   d. Materials shall be placed in accordance with the fabricator's instructions.

10. Quality Control:
    a. Quality control shall be performed in accordance with the quality control plans.
    b. Quality control shall be performed by a registered quality control auditor.
    c. Quality control shall be performed in accordance with the quality control specifications.
    d. Quality control shall be performed in accordance with the quality control quality control plans.

11. Records:
    a. Records shall be maintained in accordance with the record retention plans.
    b. Records shall be maintained by a registered records manager.
    c. Records shall be maintained in accordance with the project specifications.
    d. Records shall be maintained in accordance with the project quality control plans.

12. Site Preparation:
    a. Site preparation shall be performed in accordance with the site preparation plans.
    b. Site preparation shall be performed by a registered site preparation contractor.
    c. Site preparation shall be performed in accordance with the site preparation specifications.
    d. Site preparation shall be performed in accordance with the site preparation quality control plans.
### 2 | DEVELOPMENT LENGTH AND SPLICE DETAILS

#### TYPICAL NON-REINFORCED STRAIGHT BAR DEVELOPMENT LENGTH SCHEDULE

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<tr>
<th>BAR SIZE</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
<th>#9</th>
<th>#10</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN LENGTH (in)</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>DEPTH (in)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

#### TYPICAL SEISMIC BAR DEVELOPMENT AND SPLICE LENGTH SCHEDULE

<table>
<thead>
<tr>
<th>BAR SIZE</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
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</thead>
<tbody>
<tr>
<td>MIN LENGTH (in)</td>
<td>4</td>
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<tr>
<td>DEPTH (in)</td>
<td>1</td>
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<td>2</td>
<td>3</td>
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<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

#### DEVELOPMENT LENGTH AND SPLICE DETAILS

1. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS. LENGTHS INDICATED IN SCHEDULE SHALL BE MULTIPLIED BY 1.34 FOR LIGHTWEIGHT CONCRETE APPLICATIONS. LENGTHS INDICATED IN SCHEDULE SHALL BE MULTIPLIED BY 1.5 FOR SEISMIC APPLICATIONS. LENGTHS INDICATED IN SCHEDULE SHALL BE MULTIPLIED BY 1.34 FOR LIGHTWEIGHT CONCRETE APPLICATIONS. LENGTHS INDICATED IN SCHEDULE SHALL BE MULTIPLIED BY 1.5 FOR SEISMIC APPLICATIONS.

2. FOR LIGHTWEIGHT CONCRETE APPLICATIONS, LENGTH INDICATED IN SCHEDULE SHALL BE MULTIPLIED BY 1.34 FOR LIGHTWEIGHT CONCRETE APPLICATIONS. LENGTH INDICATED IN SCHEDULE SHALL BE MULTIPLIED BY 1.5 FOR SEISMIC APPLICATIONS.

3. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

4. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

5. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

6. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

7. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

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9. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

10. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

11. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

12. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

13. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

14. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

15. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

16. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

17. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.

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50. ALL LENGTHS INDICATED IN SCHEDULE APPLY TO NORMAL WEIGHT CONCRETE APPLICATIONS.
SHEAR WALL REINFORCING

PER ELEVATION

26' - 0" X 6' - 0"

3' - 0"

12' - 0"

#4 @ 12" E.F. (TYP.)

#4 @ 12" E.F. (TYP.)

TOP OF WALL

12' - 0"

TOP OF WALL

12' - 0"

S.O.G.

0' - 0"

S.O.G.

0' - 0"

#7 @ 16" (T) TRANSVERSE

(8) #5 (T) LONGITUDINAL

(8) #5 (B) LONGITUDINAL

#7 @ 16" (B) TRANSVERSE

2x4 CONTINUOUS
SHAPED KEY

TOP OF FOOTING ELEVATION

PER PLANS AND SHEAR WALL ELEVATION

DOWELS TO MATCH SIZE and
SPACING OF VERTICAL
REINFORCING

SHEAR DOWELS - PER PLAN
LOCATE AT MID-DEPTH OF SLAB
ON GRADE

TOP OF WALL ELEVATION

PER PLANS AND SHEAR WALL
ELEVATION

20' - 0"

G

F.1

JI THESIS

6/6/2018 3:47:06 PM

S2.4

1 WALL PLAN SECTION - N/S

2 WALL SECTION ELEVATION - N/S

3 RAMMED EARTH WALL ELEVATION - GRID 7

RAMMED EARTH WALL ELEVATION

GRID 7

WALL SECTION ELEVATION

N/S

WALL PLAN SECTION

N/S

1" = 1'-0"
SHEAR DOWELS - PER PLAN
LOCATE AT MID-DEPTH OF SLAB ON GRADE
DOWELS TO MATCH SIZE and SPACING OF VERTICAL REINFORCING
TOP OF FOOTING ELEVATION PER PLANS AND SHEAR WALL ELEVATION

16 FT. x 4 FT.

3 RAMMED EARTH WALL ELEVATION - GRID G

2 WALL SECTION ELEVATION - E/W

1 WALL PLAN SECTION - E/W
FOUNDATION NOTES
1. SEE GENERAL NOTES ON S1.1 FOR SPECIFICATIONS.
2. REFER TO FOOTING SCHEDULE FOR SITE, THICKNESS, AND REINFORCING.
3. CENTER COLUMNS ON GRIDLINES UNLESS NOTED OTHERWISE.
4. SEE ARCHITECTURAL DRAWINGS FOR TOP OF CONCRETE SLAB ON GRADE.
5. PROVIDE CONSTRUCTION JOINTS & WEAKENED PLANE JOINTS IN SLABS ON GRADE.
   REFER TO S2.3 FOR APPROPRIATE CONTROL JOINT (C.J.) DETAIL.

FOOTING SCHEDULE

<table>
<thead>
<tr>
<th>MARK</th>
<th>SIZE</th>
<th>THK.</th>
<th>REINFORCING</th>
<th>REMARKS</th>
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<tbody>
<tr>
<td>F1</td>
<td>4' X 4' X 0&quot;</td>
<td>2' - 0&quot;</td>
<td>(5) #6 EACH WAY (B)</td>
<td>SEE DETAIL 3/S2.4</td>
</tr>
<tr>
<td>F2</td>
<td>4' X 4' X 0&quot;</td>
<td>2' - 0&quot;</td>
<td>SEE DETAIL 3/S2.5</td>
<td>SEE DETAIL 3/S2.5</td>
</tr>
<tr>
<td>F3</td>
<td>4' X 4' X 0&quot;</td>
<td>2' - 0&quot;</td>
<td>SEE DETAIL 3/S2.6</td>
<td>SEE DETAIL 3/S2.6</td>
</tr>
</tbody>
</table>

NOTES:
1. USE 12" MIN SPACING FOR ALL REINFORCING IN ALL FOOTINGS.
2. REFER TO X/S2.3 FOR TYPICAL DETAIL.
3. REFER TO S2.4 & S2.5 FOR SHEAR WALL FOUNDATIONS F2 & F3.

12" THICK RAMMED EARTH WALL

INDICATES RAMMED EARTH SHEAR WALL.
REFER TO S2.4 & S2.5 FOR TYPICAL DETAILS.
INDICATES NONSTRUCTURAL WALLS.
INDICATES CONCRETE SPREAD FOOTING.
REFER TO X/S2.3 FOR TYPICAL DETAIL.
REFER TO S2.4 & S2.5 FOR SHEAR WALL FOUNDATIONS F2 & F3.
ROOF FRAMING PLAN NOTES:

1. SEE GENERAL NOTES ON S1.1 FOR SPECIFICATIONS
2. SEE ARCHITECTURAL DRAWINGS FOR TOP OF ROOF ELEVATIONS, WALL OVERALL DIMENSIONS, AND LOCATIONS OF OPENINGS NOT INDICATED ON STRUCTURAL DRAWINGS.
3. CENTER COLUMNS ON GRIDLINES UNLESS NOTED OTHERWISE.
4. "-" INDICATES RAMMED EARTH SHEAR WALL
5. "-" INDICATES NONSTRUCTURAL WALLS

REFER TO S2.4 & S2.5 FOR TYPICAL DETAILS
Appendix C - Project Presentation Slides
Introduction

- Journeyman International Team
- Background Information
- Travel Experience
- Structural Design
- Challenges
- Conclusion

Journeyman International Team

- Humanitarian Partner: Empowering Villages
- Sponsor: Domum Architects
- Architecture Student: Dayna Lake
- Construction Management Student: Tanner Frkovich
- Architectural Engineering Students: Caleb Azevedo & Anugrah Gupta

Background Information

- Map of Rwanda, Africa
Rwandan Genocide of 1994

- Two groups: Tutsis & Hutus
- Ethnic strife based on social status
- Approximately 800,000 killed in a span of 100 days

Rwanda Today

Anugrah’s Travels

Anugrah’s Travels: Virunga Site-Visit
Project Description

- Community Center
- Library
- Education Center
- Warehouse
- Market
- Washing Station

Communication

- On-site representatives: Carly Althoff & Daniel Klinck
- Advisor: Al Estes
- Weekly meetings with architect

Design Criteria

- Materials:
  - Steel
  - Timber
  - Concrete
  - Rammed Earth
Rammed Earth Construction

Rammed Earth Advantages

- Temperature and noise control
- Durable and weather resistant
- Low maintenance
- Environmentally Friendly

Gravity System

Roof Framing Plan

Lateral System

- Plywood Diaphragm
- Reinforced Concrete Bond Beams
- Rammed Earth Shear Walls
- Reinforced Concrete Footings
Challenges

- Coordination with Architect
  - Lack of site information
  - Changes in footprint & material
- Aesthetics vs. Structural Efficiency
- Unfamiliar design in rammed earth shear walls

Future of Project

- Allocation of land
- Future site visits
- Possibility of construction

Conclusion

Questions?
Appendix D - Bibliography
Bibliography


