The Preconstruction of Sustainable Housing in Muhanga, Rwanda

Rachael Worstman
California Polytechnic Institute
San Luis Obispo, California

This project involved the designing and building process of a sustainable, environmentally sound housing option designed for the people of Muhanga, Rwanda. This project was initially inspired by the Earthships built in New Mexico. During the design process the Earthships' design and materials used was evaluated, then altered to better suit Rwanda based on the available natural resources and needs of the people. Rwandans have endured a traumatic history and still experiences struggle today. An example of this is the anti-thatching campaign in 2011 that left thousands of people homeless as they were forced out of their unsafe homes. One way to aid Rwandans in their healing process and give people a sense of safety is to provide a housing design that can make living sustainable and affordable. This project’s goal was to create a safe housing option that offers a level of accessibility to all through a simple design, ability to build it yourself, and use of only resources found in Rwanda. The advantageous features include, no importing of materials, off-grid water collection system, environmentally friendly, and adaptation to Rwanda's agriculture society. This paper describes the project inspiration, design process, and final design including a plan set and schedule.

Keywords: Rwanda, Sustainable, Housing, Safe, Environmental

Introduction

The concept of this project began after seeing the housing design of Earthships and hearing firsthand accounts of the building process from a peer. The Earthship Biotecture organization successfully created a sustainable off-grid housing option that has been implemented throughout the United States. The design was well thought out but was expensive, thus it was not attainable for people of lower economic statuses. The need of a sustainable, simply designed home that all people can afford would help the planet, reduce carbon emissions during the construction process, and better the quality of living everywhere. This realization inspired the idea of implementing sustainable homes throughout the world. Not only would this design help the environment, but it would benefit the local economy of places like Rwanda where local craftsmen and laborers would have an abundance of work and it would allow people to build their own homes. The purpose of this paper is to discuss the process that occurred to create a finished design and preconstruction plan for a sustainable housing option in Muhanga, Rwanda.

Design Process

Research

The research process began by evaluating and understanding the design of Earthships created by Earthship Biotecture. The design was simple and highly effective, but the materials used were not appropriate for Rwanda. The research was then directed to more simple adobe homes and how they were constructed. The type of soil needed to make strong adobe bricks needs to be clay soil with low to medium plasticity, which is abundant in Rwanda. Thus, the main building material that would be
used is adobe bricks which have high strength and double as a great thermal insulator, keeping the house cool during the day and warm during the night as the bricks release stored heat from the sun. Adobe bricks are dense, resulting in a wall weight of about one thousand pounds per foot, thus altering the size of the footings to be larger to accommodate this load. Cast inside of some bricks will be glass or plastic bottles to allow additional natural light, in as seen in the Earthship homes and other projects throughout the world that Erik Brinkman (SME) brought forth. Another key aspect of the research was finding a suitable roofing material and support system. Most homes in Rwanda have tin roofs, but these are not sustainable or suitable for water run-off collection. A terracotta tile roof was chosen because they can be bought in Muhanga, or hand made on site. They have an eighty-five percent run off rate that offers a clean and natural solution compared to tin. The framing for the roof is Eucalyptus, which is naturally sourced in Muhanga and is strong enough for framing. Through the research process different materials and assembly options were explored based on the conditions and resources in Muhanga and what would be more affordable and improve safety.

**Interviews**

After most of the research phase was completed, interviews were conducted with people who have worked in Muhanga and people who are experts in the construction field. Paul Flerchinger was the first person to be interviewed. Paul works for Zipline, a company that delivers blood products to over 21 hospitals in Rwanda via drones. Paul worked in Muhanga for a year setting up a Zipline location that would deliver blood products to local hospitals. The time Paul spent there offered a real image of what the housing in Muhanga looked like, the materials used, the weather, and what resources could be used. The firsthand experiences and images that Paul shared paved the way for the design and what materials could be used based on observations while in Muhanga. Ryan Kline was the next person to be interviewed. Ryan has been a project manager, as well as holding many other jobs in the construction industry. With, years of experience in the industry, foresight to recognize and plan for future issues, and the cultural experiences gained from Ryan’s service in the Marines had a large impact on the practicality of the design. Issues that arose during our discussions were about the global shipping crisis, the inability to import goods into Rwanda, and cultural aspects that could affect the size of the home. It was very apparent that shipping materials to Rwanda would not be feasible because of the COVID-19 shipping crisis, expensive air freight costs, and political turmoil between countries in Africa, making it uncertain if driving materials across multiple boarders was even possible. Another issue discussed was the size of the houses. During Ryan’s time in Hong Kong with the Marines, he learned that the culture norm was for the extended family to live together, affecting the size of the home or quality of living. This was taken into consideration when deciding the number of bedrooms in the housing design. The solution factored in the average size of a single family in Muhanga for the original design, and created an alternative for larger families or extended family to live under the same roof.

**Problem Solving**

After conducting research and interviews there were many problems that needed to be addressed to make this project feasible. One problem that was discussed with Ryan Kline was the inability to import goods into Rwanda because of the land locked location. This altered the design greatly. Importing materials like large windows and solar panels would be too expensive and make these homes only for the wealthy, which is not the goal of this project. The solution to replace glass windows was to use locally sourced shutters with locks for all window openings. No solar panels meant the homes do not have electricity. Not having electricity was not ideal, but most homes in
Muhanga do not currently have electricity already and the addition of more windows and bottles in the walls allow for more natural light in the home. Without solar panels these homes would be reliant on electricity from the city, therefore not self-sustaining. Although there is no electricity, there is a full plumbing system that uses rainwater collected in the cisterns that can be used as drinking water and water for the shower, bath, and sink. Water is then reused as grey water to flush the toilets and water the indoor greenhouse plants. Finally, the black water is drained outside of the house and used to water and fertilize the outdoor garden. This plumbing system is possible due to Muhanga’s monthly consistent rainfall totaling 1200mm in a year and the use of only gravity and hand pumps for a fully functioning system that David Worstman helped design. The cisterns used in this system are designed to be hand build using naturally sourced materials as other neighboring countries have done. This practice cuts down costs, is customizable, and is environmentally conscious. Although this home is already inexpensive, certain adaptations can be made to make this home even more economical. The toilets used in the original design are standard toilets with a handwashing basin tank cover. These toilets could be replaced with composting toilets if needed. Similarly, the plumbing system could be removed entirely if it is not needed and only a filtered cistern would remain to be used as drinking water. The entire footprint of the home could be made smaller or larger depending on the needs of the people that it is being built for. Similarly, the use of bottles in the walls and number of windows can be changed depending on preferences. To make this accessible and attainable for people of all economic statuses these are the alternatives that could make this design simpler and lower cost.

**Design**

The initial iterations of this design were done in Procreate where the size of the building, layout, and details were worked out. After the initial sizing was done and materials were chosen, the design was modeled in Revit. The size of the house and number of bedrooms were based off the average size of a family in Muhanga, which according to statistics.gov is about 4.7 people. The materials decisions were made after the research and interview phase of the design process. All walls of the house are made of handmade adobe bricks, with some designated bricks containing glass or plastic bottles to help with natural lighting. The roofing system is designed to use eucalyptus logs as the framing lumber for the roof, then an adobe mud mixture laid over top, and finally terracotta tiles that can be sourced in Muhanga or handmade on site. The footing and flooring system of compacted soil, gravel layer, and a finished adobe floor was chosen after researching building codes, considering the weight of the finished walls, and finding the most resourceful, long lasting flooring option. After many hours of research, interviews, and design iterations the final design was modeled in Revit.

**Preconstruction**

**Plan Set/Drawings**

After the modeling was completed in Revit the floor plans were exported and drawn in Procreate. Hand drawn details and notes were added to better understand every aspect of the house and the building process.
Figure 1. House Floor Plan

Figure 2. House Elevations East & West
Figure 3. House Elevations North & South

Figure 4. House Sections South & West
Figure 5. House Footing Plan

Figure 6. House Plumbing Plan
Figure 7. House Roofing Plan

Figure 8. House Details
Creating the Schedule

The basic estimated schedule was created after completing the model and plans then conducting calculations. The number of bricks needed was calculated based on the height and thickness of walls, the size of the adobe bricks, and area of walls. The amount of time to assemble the walls will vary based on weather and crew size, but this schedule is based on a crew of seven to ten people that can lay about 300 bricks a day. There are multiple activities that occur simultaneously, so a larger crew size at the start of the project would accelerate the schedule and could allow for a smaller crew at the end of the project to keep costs down. This schedule is assuming that the crew would be excavating and grading using only hand tools, no heavy machinery, due to location and cost. Similarly, the schedule assumes that part of the crew will be hand making the adobe bricks and the roof tiles, which would save on costs considerably, but lengthens the schedule more than if they were bought locally. In Figure 8 the schedule can be found showing the general sequence of events and having a duration of 96 days in ideal conditions with a crew of seven to ten people.

Conceptual Budget

A formal budget was not created due to lack of specific prices and information regarding the materials and labor in the area. The cost of labor would have the greatest impact on both the schedule and the cost of the project, as this house relies heavily on the labor to make all the adobe bricks and lay them to make all walls. The cost of cabinets, shutters, and toilets in Rwanda are the items that would need to be bought or manufactured. Pricing on these items were not found in the research that was conducted but would affect the budget. For these reasons named an accurate budget cannot be given at this time.

Future Hopes for This Project

The next part of this project would be to get all drawings approved by engineers and architects, then partner with a company and take this to construction phase in Muhanga. This is an attainable goal as peers and professors have encouraged me to present this project to the Gates Foundation or to Engineers without Boarders to make this more than a preconstruction project. With time and the correct networking, it is highly possible that these homes will be future dwellings in Muhanga and other parts of Rwanda.
Lessons Learned

Throughout this research and design process I learned an unbelievable amount about Muhanga and how much detail is needed for a preconstruction set. During the interview process many people were telling me that this project was not possible and that there were too many challenges. Through more research and interviews I was able to come up with viable solutions to these problems. During the creation of the drawings and 3D modeling I would think that I was finished with one drawing but realize that there were more details that needed to be added so people could fully understand them. The amount of details, time, and problem solving that went into this design was much more than I had expected, but it made it a very gratifying experience. In addition to becoming a better problem solver and more detail oriented, my modeling skills in Revit excelled as I had to find a way to accurately model the ideas in my head. I learned that the most important part of any project is being able to accurately illustrate your ideas so that others can understand it whether that is with drawing, modeling, or verbal presentations.

Conclusion

In conclusion, the design and preconstruction drawings of sustainable housing in Muhanga was a success that can be further pursued. The author intends to see this project through in Rwanda after graduation by partnering with either the Gates Foundation or Engineers without Boarders. This senior project took the author’s passion for affordable housing and sustainability and created a tangible product that has a future in this world. There were many lessons learned throughout this project that impacted the author as a person and will make them a more well-rounded person in the construction industry. Now that the design and preconstruction phase is complete, the author will take this project to the next step and see it through completion.