DESIGNING A *ROGEMMA* BEE HOUSE: IMPROVING APICULTURE IN SHEEMA DISTRICT IN UGANDA.

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DECLARATION

I, Murunga Roger solemnly declare that the work contained in this thesis is my original work and has never been submitted to any other University for an academic award.

Signature…………………….

Date………………………….

APPROVAL

This thesis is produced by the researcher and its content is original.

Signature………………………………

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2nd Supervisor

Date:……………………………….

DEDICATION

The content of this thesis is dedicated to apiculturists along the cattle keeping corridor of Uganda.

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I wish to in particular express my sincere gratitude to my principal supervisor Dr. Mutungi Emmanuel for the immeasurable relentless effort and time rendered to me during my entire research. Similarly, I want to appreciate my second supervisor Mr. Gyaviira Mugyenyi for his contribution to the success of this research. I also wish to thank the entire academic staff of the Department of Art and Industrial Design for their moral support at the time when I needed it most. Finally, I wish to appreciate all the respondents that I interacted with during my research for the treasured information rendered to me hence contributing to the completion of this research.

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DEFINITION OF TERMS

Apiary:	A shed containing a number of beehives.
Customer:	Apiculturist
Local materials:	Materials that belong to or are characteristic of a particular locality or neighborhood
Rogemma Bee House:	A locally constructed structure with inbuilt beehives, extraction space and water reservoir. The name was derived from Roger and Emmanuel who were Part of this research.
Safety:	A state of resilience from theft and vandalism
Theft:	The act of taking honey from one's beehive, or taking the beehive itself without seeking permission from the owner of the beehive.
Vandalism:	A deliberate act of destroying, defacing or damaging of one's beehive with the intention of stealing honey.

LIST OF ABBREVIATIONS

AUBTG: Africa Uganda Business Travel Guide

BFC: Beekeepers For Christ

CADD: Computer Aided Drafting and Design.

KBT: Kenya Top Bar

RBH: Rogemma Bee House

URA: Uganda Revenue Authority

WBC: William Broughton Carr

ABSTRACT

Production of honey in Uganda is a remunerative business. Honey has high demand both for medicinal and nutritional importance across the entire world. Majority of apiculturists use indigenous beehives that are a target to thieves and vandals who raid the beehives resulting to devastation of many bee colonies. Besides that, these hives have a limited capacity to host bees therefore bee keepers are compelled to buy multiple separate beehives so as to boost the quantity of honey produced making the business overall expensive. Land is continuously being fragmented and farmers have limited land for spreading beehives. The Study was intended to design and produce a model RBH with a manual which will ensure safety of the bees against vandalism and theft. Secondly, the design is intended to enable apiculturists improve quality and quantity of honey, and provide a manual for production of the RBH. The study was qualitative and used an exploratory approach whereby apiculturists were interviewed and observed on how they engaged in apiculture. The study hopes to raise the production, quality and quantity of honey in Sheema District and generally in the entire cattle corridor in the Western part of Uganda where households are engaged in honey production. The success of this project is expected to contribute not only to the body of knowledge, but also to the increased food supply for sustainable development as bees are primary pollinators in agriculture.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Overview

This section highlights the background information of apiculture, the statement of the problem, objectives, research questions, theoretical framework, the scope of the study and the justification of the study.

1.2 Background information of apiculture

The honey-bee is one of the best-known insects, whose relationship with humans can be traced back to the dawn of humankind when man collected honey from wild bees' nests. Cramp, (2008) shows a cave painting in Cueva de la Araña in Spain (figure 1.2.1) of a man harvesting honey from a beehive.

Figure 1.2.1 Drawing of a painting from the caves of Cueva de la Araña showing a human collecting honey from the bees.
Source: https://en.wikipedia.org/wiki/File:Cueva_arana.svg

Beekeeping has become one of the lucrative businesses today due to the increasing demand of honey for both nutrition and medicinal value globally. The Africa Uganda Business Travel Guide (AUBTG, 2018) noted that honey in the African culture is used for beverage brewing and occasionally served at important cultural ceremonies such as weddings, it is also served to very important guests as sign of high regard. Honey has also been used for other purposes for very many years; The Maji Maji rebellion used bees as a weapon to defend themselves against the colonialists, honey was likewise used in Egypt as cosmetics and also for embalming the Egyptians dead pharaohs and was among the tithes and offertory given by the Jews to the Levites in their culture. Finally, in some African cultures, honey is also used to pay dowry (AUBTG, 2018).

This useful product- honey- produced by bees, led man to engage in beekeeping in order to have more access to it. Various traditional methods of beekeeping have been adopted from the past; they range from the use of tree trunks to clay vessels that have been used as beehives. In Uganda traditional methods of beekeeping are still common though they face many challenges. Ochan, (2018) noted that hives are usually destroyed and colonies often killed in the process of collecting honey. That is associated to the fact that such hives are always enclosed without provision of opening them up to conveniently access the honey. The bees build their combs on the internal surface of the hives and that compels the breaking of the hives to access honey.

Due to limited availability and improper use of harvesting equipment, honey becomes susceptible to contamination and adulteration. The resulting low-quality honey cannot enter the formal market chain, but ends up in the informal markets being used as an ingredient for making local brews or herbal products (Chitalu, Garibay & Ssebunya, 2011). A few keepers have modern honey presses but, more commonly, honeycombs are pressed by hand. Much of the honey produced has impurities, including wax and bee parts. Those who have invested in pressing machines produce better quality honey (Ochan, 2018). However, that may not necessarily be the only cause of honey contamination as the quality could greatly be influenced by how it is handled through the process of harvesting. If hygiene is guaranteed and harvesting methods and environment controlled, pure honey could be achieved.

Beehives are traditionally constructed from timber, bamboo boruss palms or woven from forest climbers. Unfortunately, hives are sometimes crudely raided at night with the use of grass torches and fire to smoke out the bees leaving many colonies destroyed (Ochan, 2018). Such barbaric acts can be minimized if the perpetrators' efforts to access the honey are made more difficult though the design and materials used to construct the beehives. Warre (2009) observes that there are several wood varieties that are good for constructing beehives. He notes that pine is the most popular, with cedar a close second. These woods tend to be used more often than hard woods because of less weight. Soft woods are always less expensive as well, compared to the hard woods such as oak, or maple.

Chitalu and Ssebunya (2011) posit that the bees are destroyed by different pests such as the varroa mite as well as other pests that are threatening beekeeping in Africa, and farmers lack knowledge on their proper management. Smagghe (2017) observed that one of the threats of bees is the massive numbers of small hive beetles common in Uganda that can be a destructive pest of honey bee colonies, causing damage to comb, stored honey and pollen. Besides that, Smagghe, *ibid* noted the challenge of poor apiary husbandry, especially in the migratory beekeeping system, but also in fixed apiary system, where bees are left to look for their own forage, water and to provide their own security from invaders. During times of scarcity, such as dry seasons, hives swarm and abscond and hence the farmer loses potential yield from such hives. Beekeepers For Christ (BFC, 2003) found out that Uganda produces less honey than it consumes and therefore importing honey from Sudan and other countries. Ochan (2018) noticed that The Ugandan Beekeepers Association estimates that only between 800-1200 metric tonnes of honey is produced per year due to current lack of bee stock and that the Association has introduced improved wooden hives costing about US$15 (Uganda shillings 25,000), which can be opened for checking honeycombs and reduces the damage inflicted to a colony. The present study argues that the intervention may not be sustainable because most of such improved wooden hives are light and suffer vandalism and theft therefore will in turn discourage bee keepers as a result of the losses they make. On the other hand, the climate changes coupled with long dry spells leads to the destruction of the beehives as they become so hot that they affect the honey by lowering its viscosity thus causing it to flow from the beehives which may attract pollutants that would intern affect its quality.

1.3 Statement of the problem

The economic value of honey keeps increasing because the benefits of honey have been greatly recognized in the food and medicine industry both nationally and globally yet, in Uganda, the quantity and quality of honey keeps reducing because of theft of honey and destruction of bee colonies. The current beehives on the market are susceptible to prevalent challenges such as vandals breaking into beehives to steal honey and thieves stealing beehives themselves. In Uganda, various types of beekeeping structures have been developed since ancient days to the present age with an aim of increasing honey production. However, most of these beehives do not have a proper mechanism to prevent stealing of honey or the beehives themselves. Consequently, various effects such as, loss of honey, death of the honey bees, swarming of the bee colony, loss of the beehives and low quality and decreased quantity of honey characterize the apiculture. If these challenges are unattended to, they will result to continuous economic losses to the beekeeping investors. Apart from the losses, the bee population which is a major booster of pollination in plants will face the threat of extinction thus create a shortage in food production which will result to hunger. There is need for an immediate intervention to protect the bees, the honey as well as the hives themselves from vandals and thieves since apiculture is a source of income to many households, honey is medicinal and its scarcity could pose a great health challenge to humanity.

1.4 Purpose of the Study

The purpose of the study is to design an RBH that will combat honey theft and hive vandalism, protect the bees and provide a hygienically conducive honey harvesting environment for farmers in Sheema District, Western Uganda.

1.5 Objectives

1) To analyze the quantity and quality of honey among apiculturists in Sheema District, Western Uganda.

2) To develop designs of RBH for apiculturists that will improve the quantity and quality of honey harvested.

3) To produce a prototype of the RBH with a manual for apiculturists.

1.6 Research questions

1) What is the cause of poor quantity and quality of honey among apiculturists in Sheema District, Western Uganda?
2) How can RBH that improve the quantity and quality of honey be designed?
3) How can RBH that promotes quantity and quality of honey be produced for apiculturists in Sheema District?

1.7 Scope of the study

The research will be defined by both area (geographical) scope and content scope so as to ease its execution within the expected time frame.

1.7.1 Geographical scope

To enable the researcher, acquire substantive information, the research will be conducted around Sheema District since it will be easy for the researcher to access several stake holders that are involved in beekeeping practice.

Figure 1.7.1 Cattle corridor of Uganda (Yellow)
*Source:*https://www.researchgate.net/figure/Map-of-Uganda-and-selected-key-features_fig1_260383730

Figure 1.7.2 Sheema county (Red)
Source: https://www.google.com/imgres

1.7.2 Contextual scope

Whereas apiculture might face unlimited challenges, the researcher intends to address the challenge of quantity and quality at the production level which stands out as the most prevalent reason as to why honey from Sheema cannot substantially contribute to the formal market chain.

1.8 Significance

The research on designing RBH for apiculturists in Sheema District, Western Uganda is expected to contribute to the existing body of knowledge in the field of apiculture in Uganda and benefit the stake holders in the following ways:

Provide source of information which will be utilized by scholars and researchers both nationally and globally who wish to not only enlighten themselves but also further drive or advance the conversation of apiculture.

Provide information which will be utilized by the community in Sheema District to ameliorate apiculture practice which will result in improved source of income. It will also build unity and collaboration in the community as some of the apiculturists will engage in collective building, ownership and management of the RBH. Crop farmers will experience improved yields as a result of plenty of bees which are the major source of pollination.

Increased honey production influenced by the RBH will result to increased revenue collected by URA which will profitably contribute to the economy of the nation and finally, encourage policy makers to develop policies that will promote apiculture as its national economic significance will be greatly realized.

1.9 Theoretical framework

This research is informed by the “Contextual Design Theory” that was developed by Karen Holtzblatt and Hugh R. Beyer in 1998 (Claude, 2005). It is a structured, well-defined user-centered design process that provides methods to collect data about users in the field, interpret and consolidate that data in a structured way, use the data to create and prototype product and service concepts, and iteratively test and refine those concepts with users. The core of the Contextual Design philosophy is to understand users in order to find out their fundamental intents, desires, and drivers. Usually, the theory therefore enables the researcher to go out in the field and talk with people.

The best product designs will therefore happen when the product's designers are involved in collecting and interpreting user data so that they can appreciate what the users need. This theory helps the designer to decide on what the users of a product need and how to design a product for them.

Contextual Design prescribes interviews that are not pure ethnographic observations, but involve the user in discussion and reflection on their own actions, intents, and values. The interviewer actively questions the user and partners with them to draw out and understand their work practice in detail. The interviewer thus does not enter with a preformed list of questions, as in a survey or focus group, but rather adopts a *master-apprentice relationship model,* seeking to understand the user's work as an apprentice would from a master, as the work is ongoing.

Contextual Design Theory is benchmarked by seven parts of which the first is the ‘Contextual Inquiry’, which involve understanding the end-users of the solution, who in this case are the apiculturists. This uncovers who apiculturists really are and how they work on a day-to-day basis to understand their needs, their desires and their approach to apiculture. The researcher therefore gets involved in apiculture so that he may understand how apiculture is done.

The second part is the ‘Work Modeling’, where *work models* are used to capture the work of individual user. This therefore captures the work of individual apiculturist in diagrams to provide different perspectives on how they keep bees. The researcher therefore takes note of how each independent apiculturist manages the bees using their various beehives and methods.

The next part is ‘Consolidation’ which brings data from individual user interviews together so as to observe a common pattern and structure without losing individual variation. The affinity diagram brings together issues and insights across all users into a wall-sized, hierarchical diagram to reveal the scope of the problem. It involves bringing data from individual apiculturist interviews together so that the designer (researcher) can see common pattern and structure without losing individual variation. The researcher then gathers all that information and seek to find common trends of merits and demerits of their beekeeping methods relative to their beehives.

The succeeding stage is ‘Work redesign’, which provides for this structural design through storyboards and the User Environment Design, and then validates the design through paper prototypes. The researcher uses the consolidated data to drive conversations about how to improve apiculture by using technology to support the new beekeeping practice. The researcher therefore uses the consolidated data to come up with various designs of RBH that improves beekeeping practice among the farmers and develops by the technology of computer aided design (CAD) that prescribes ultimate production in strong materials such as concrete and bricks.

The next stage is the ‘User Environment Design’ which captures the floor plan of the new system. It shows each part of the system, how it supports the user's work, exactly what function is available in that part, and how the user gets to and from other parts of the system. The researcher captures the floor plan of the new design and each part of the design and how it supports the apiculturist’s work, exactly what function is available in that part, and how the bee keeper gets to and from other parts of the beehive. In this stage, the researcher demonstrates how the apiculturist will relate with each part of the RBH and how such parts will increase the efficiency of work within the RBH and safety of the bees as well. The next part is the ‘Test with customers’, where paper prototyping develops rough mockups of the system using Post-it to represent the different parts of the beehive. At this stage, the researcher will present prototypes to the apiculturists and seek their opinions concerning the new design of the RBH.

Finally, is the ‘Putting it into practice’ which involves the translation of the prototypes into object-oriented designs and implementation which will happen after the researcher submits the construction manuals to the relevant stakeholders for implantation of the RBH construction.

The core elements of Contextual Design have been stable for many years and are unlikely to change basically in the future. However, the context in which Contextual Design is used may change and that is likely to drive changes in how the process will be used.

Preece, (n.d.) notes that contextual design has stood the test of time because first, it was a timely solution to a real problem. Second, it is structured, rigorous and systematic. Third, it respects the needs of real users by enabling them to be partners in the design process.

Fourth, it can be adopted and adapted by a wide range of designers from student learners to researchers to professional designers. And fifth, it is challenging and fun! The contextual design theory will therefore be the most relevant theory to this study because it will use the knowledge acquired from apiculturists to design RBH that will respond to their needs and desires as far as apiculture is concerned.

1.10 Researcher's Positionality

I am a graduate architect from Makerere University and a part-time lecturer at Kyambogo University in the Department of Art and Industrial Design in the section of Interior Design. Having graduated in 2013 from Makerere University, I begun to ponder on how best to use my knowledge to assist my father who is a small-scale farmer improve his income having invested so much in my education. That was the moment when I realized that I could use the knowledge acquired at school to offer him design solutions in form of simple structures in the farm such as poultry house, multipurpose cow shed among others which solved his immediate challenges of space and financial costs. It was at that point that I realized that my knowledge was able to serve as a solution to a farmer when I began to witness the fruit of my efforts having engaged in each design challenge.

While engaging in my teaching practice at Kyambogo University, I developed a strong attachment to Interior Design course. I discovered that there was a great interrelationship with architecture which I had pursued for my bachelor's degree. I specifically developed passion for space planning which involved solving spatial challenges in a built environment. One evening, on my way home, I happened to get a ride from Dr. Mutungi Emmanuel who is our head of department at Kyambogo University. While conversing, I noticed that he had interest in Apiculture. That sparked my curiosity because I remembered how much I loved a sandwich of honey yet I was less informed about apiculture! As the conversation rolled out, I noticed that his concern was how he could secure many beehives safely within a minimal space. Remembering how I had been instrumental to my father who is a farmer, I realized that this was the ultimate moment for me to investigate into that subject of apiculture, gain knowledge, identify a problem gap and finally with the background of architecture and the knowledge of space planning, provide a design solution that would not only be beneficial to Dr. Emmanuel Mutungi, but also beneficial to apiculturists in Uganda. It was therefore with this background that the present study was conceived

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter investigates, analyzes and interprets various literature, both current and those in the archives about apiculture. The goal is to enable the researcher and the readers to be acquainted with relevant knowledge in the target research area. It also helps the researcher to develop an understanding on how various scholars have consciously or subconsciously addressed courses of shortage and poor quality of honey with respect to various beehives across the globe. The literature is arranged and presented in this chapter according to the objectives of the study.

2.2 Designs of beehives

Beehive

Nettleingham and White (2008) observes that a hive is any space or box in which bees can set up their home. Whereas this definition is true, it does not in any way attempt to set a standard that makes beehive a habitable home for bees, and as a result, many bee swarms have suffered high mortality rate due to vandalism of the hives and predators. It does not also in anyway describe a quality environment that can guarantee clean honey from the bees as well

Many beehive types have been designed from ancient days ranging from indigenous to contemporary ones, each of them having its merits and demerits. One of the goals has been to increase honey in the market. In this journey of beehive design, (Beegin, 2018) noted that Elvis Brown, a master's student in South Africa found out that there seemed to be a central and standardized system for beekeeping that everyone agreed on - the Langstroth beehive, with its frames and chambers. However, for each beekeeper there was a different set of beliefs, systems, modifications, improvements and innovations that they had either chosen, or been forced to adopt - in order to cope with their specific circumstances. From harvesting to inspections, locking to protection, frames to bars, queen-manipulation to insulation, maintenance to manufacture and so on, every beekeeper had their own unique way of keeping their bees alive and well.

BFC (2003) observed that approximately 90% of the hives in Uganda are the traditional type and the other 10% are Kenya top-bar. The hives are typically an owner-built cylinder with a volume of 25 to 138 liters and made of local materials such as a hollow log, banana leaves, palm grasses, sticks, woven bamboo or lantana. Only hollow logs are used in the Yumbe district. The hollow cylinder is usually closed at both ends with a space at the front entrance for the bees to move through. No movable frames are used. However, bees build comb and place brood, pollen and honey in a somewhat predictable pattern in the hive.

In those traditional hives, due to the absence of removable frames, it is almost impossible to inspect the brood without destroying the colony. Not only is the colony destroyed, but also the honeycombs on which the bees have to deposit honey is destroyed as well. That makes it more tasking for the bees to begin rebuilding the honeycomb so that they may begin the process of depositing honey afresh, and that would in turn slow down the process of the female worker bees to make honey. Because of the highly degradable materials that are used to make such hives, by the time honey is harvested, most of the materials would have decayed and posed the challenge of contaminating the honey. It therefore becomes very difficult to ensure high quality of that honey that is harvested from such local hives.

2.3 Developing designs for RBH

Buzzaboutbees (2018) noted that in 1838, Johann Dzierzon, a Polish apiculturist, devised the first practical movable-comb beehive, which allowed manipulation of individual honeycombs without destroying the structure of the hive and that in 1962, a Museum of Apiculture was established at Kluczbork, Poland, in Jan Dzierżon’s honor.

That discovery of the movable comb should have become a big achievement in apiculture because it made it easy to work with honeycomb themselves without having to destroy the beehive itself. The researcher believes that this should have conceived the idea of honey extractors as the frames could have been handled off the beehives. With such advancements, it should have become easier to reuse the honeycombs after honey had been extracted from them hence reducing the costs of procurement or fabrication of completely new hives after every single harvest.

Besides the flexibility that had been achieved in harvesting honey, it should have greatly reduced the high mortality rate of the bees that is experienced in the local beehives. The figure 2.3.1 shows the stack of Dzierzon hives which could be pulled out to expose the combs in them.

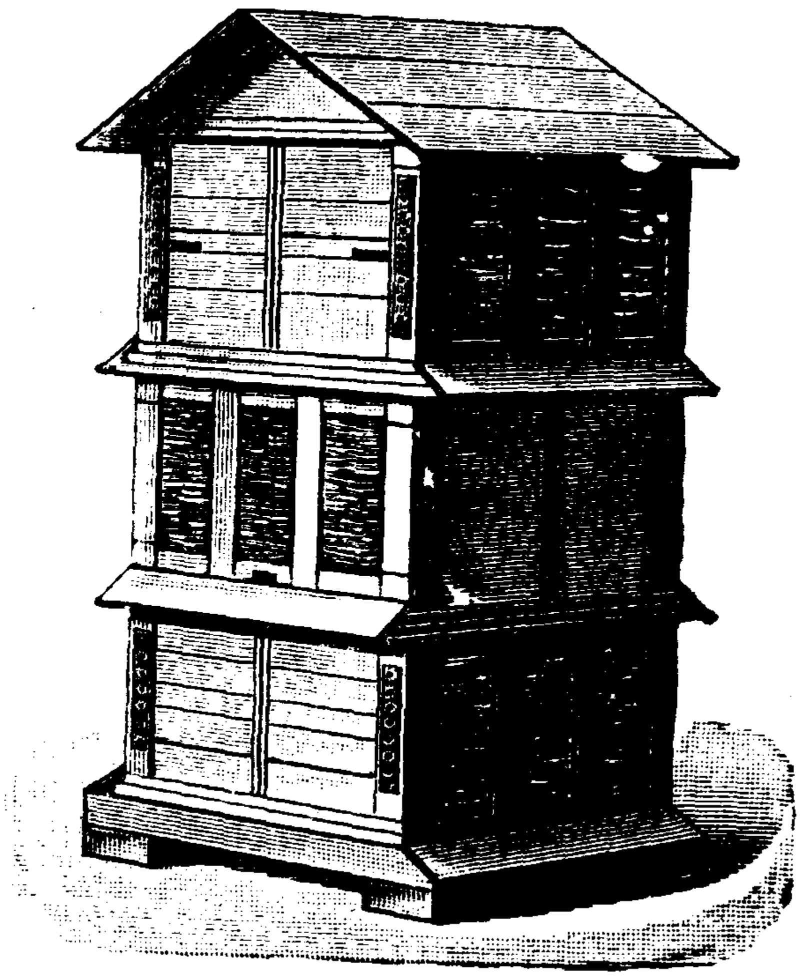


Figure 2.3.1 Stack of Dzierzon hives.
Source: Nordisk familjebok.
Year: 1905

Figure 2.3.2 Lithuania Stripeikiai Honeymaking Museum (Sculptured hives)
Source:
https://en.wikipedia.org/wiki/File:Lithuania_Stripeikiai_Honeymaking_Museum.jpg

Buzzaboutbees (2018) continues to note that in 1851, L.L. Langstroth, the "father of American beekeeping had access to translations of Dzierzon's works., built upon the design of Dzierzon, and others (such as Francis Huber of Switzerland), and designed a completely movable frame hive and also, Langstroth has been credited with discovering the "bee space," although it had already been implemented by Jan Dzierżon.

Buzzaboutbees, *ibid* also observed that in 1890, William Broughton Carr, English inventor and beekeeper, invented the WBC beehive as illustrated in figure 2.3.3. The WBC hive was made of wood and contained removable frames. The double walled nature of that hive made it very complicated to construct it. The hive also contains gable roof to protect the hive from the effects of weather.

Cushman (2011) noted that the gabled roof was made of materials such as metal, felt and canvas that was painted. He also noted that the double walled concept was to make the hives warmer during the winter seasons. In the present study, researcher is convinced that we may not need such insulation for the tropical climate in the cattle corridor of Uganda. The researcher also felt that the WBC beehive may not be cost effective for apiculturists who wish to engage in large scale apiculture as that would demand for high costs of servicing the independent beehives.

Figure 2.3.3 William Broughton Carr Beehive
Source: https://en.wikipedia.org/wiki/File:Wbchive.JPG

Conrad (2015) mentioned that Stewart and Cedar Anderson invented the Flow Hive illustrated in figure 2.3.5. That hive was invented in 2015 and it was made of wood and allowed the apiculturist to harvest honey without having to disturb the bees. By the force of gravity, the honey flows through the plastic combs as shown in figure 2.3.4 out of the hive through the end of the horse.

Figure 2.3.4 The flow hive
Source:https://www.honeyflow.com/media/images/content/thumb/og_image_wrc7-page608.jpg

Henein (2015) gave three reasons why one should not use the flow hive. Those reasons included; The use of plastic comb which is made of polypropylene which is harmful to humans and the bees don't like it either, non-existent communion between bees and apiculturists which cuts off the real feel of beekeeping and makes apiculturists more honey centric than bee centric and lastly, it is an expensive gimmick which does not mind of habitable environment in which the bees would love to live in.

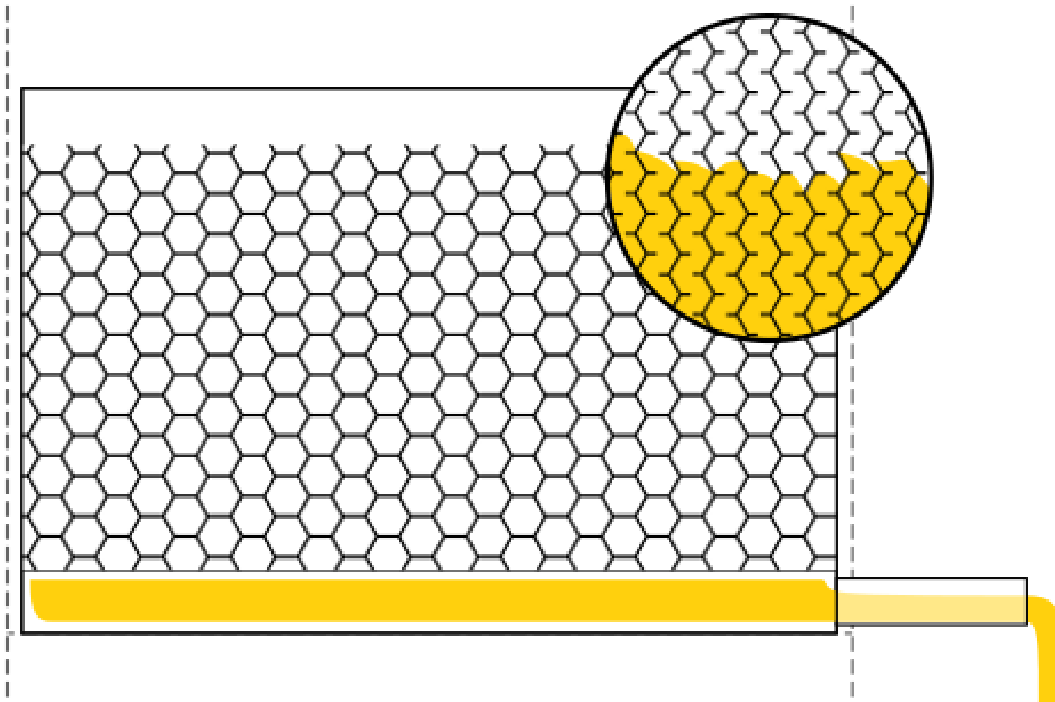


Figure 2.3.5 The mechanism of honey flow through the plastic combs
Source: https://en.wikipedia.org/wiki/File:Flow_Hive_Schema.svg

Beegin (2018) recorded that Brown, the inventor of the Bunka beehive (figure 2.3.6) discovered that the beehive design criteria highlighted several thematic areas that required improvement such as cost, durability, production speed, ease of production, insulation, harvesting system, pest exclusion and materials. The last theme was a fundamental design feature that had an effect on much of the rest of the beehive. He likewise noted that wooden beehives were relatively cheap, but they would not last long, where insulating and protecting the bees from threats required expensive machinery to make properly. Plastic-foam (polystyrene) was also cheap, but even less-durable than wood, requiring protective paint for UV protection, and while they created good insulation there had been issues with condensation and internal humidity. Composite-plastic beehives were often engineered to solve the humidity issue, but had been found to create electrostatic discharge problems (resulting in absconding swarms). More so, despite the high price these hives carried they would not last long with fires, vandalism and theft. Consequently, the plastic beehives also required specialized manufacturers in industrial locations which would turn out to be cumbersome for the local bee keepers in the cattle corridor of Uganda because of the fires and their cost.

Figure 2.3.6 Section through the Bunka hive
Source: http://www.beegin.co.za/images/cover_1.jpg

The section through the Bunka hive in figure 2.3.6 shows the use of BRC mesh to reinforce the concrete that has been used to mold the hive. That level of detailed construction may turn out to be complex for local builders who may have interest in the Bunka hive. Not many apiculturists may also be able to access the molds that are used to cast that hive. It would likewise be a challenge for interested apiculturists to be able to import the Bunka hive all the way from South Africa due to transport implications.

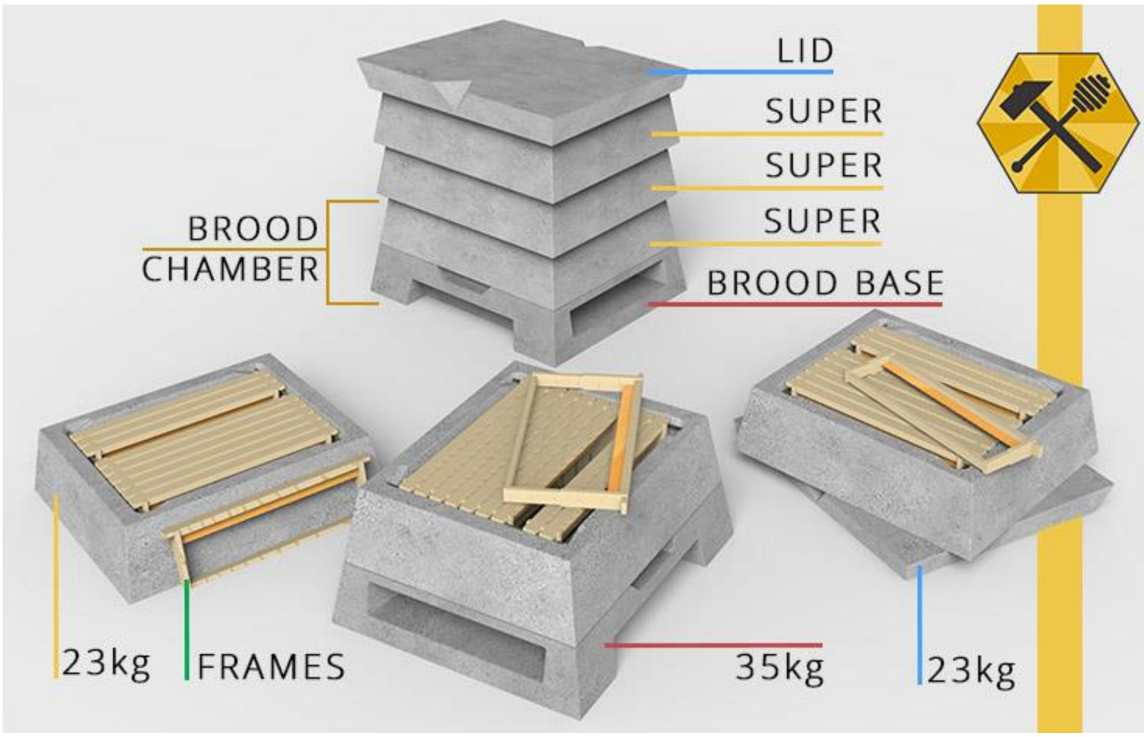


Figure 2.3.7 The different parts of the Bunka hive
Source: http://www.beegin.co.za/images/bunka_story.jpg

Whereas the Bunka hive addresses the challenge of insecurity, the massive weights as illustrated in figure 2.3.7, of the lid and the supers which apiculturists have to lift in order to inspect or harvest honey would require a lot of energy hence it would be hectic for an apiculturist having many of such hives to harvest honey. The Bunka hive would thus be effective only for small scale apiculturists but burdensome to large scale apiculturists.

The beehives are installed in different ways depending on the objectives of the apiculturists. Some apiculturists who practice for domestic consumption will always install them anywhere of convenience such as in the backyards of their homes. Many times, the hives will not always be far from their homes while the apiculturists who practice for commercial purpose will always seek a spacious locality where to install the hives which are always many in numbers and always tend to have them fairly away from people's homes. A typical example is one shown in figure 2.3.8.

Figure 2.3.8 Beekeeping in Vietnam
Source:http://2.bp.blogspot.com/-yWQ8abpkYuw/T0-ug9gFcOI/AAAAAAAAAXU/XRsRqwGJiS4/s1600/IMG_0456.jpg

2.4 Production of a prototype with a manual of the RBH

Beegin (2018) noted that Brown's idea of using concrete as a material came up along with some other concepts, but in a discussion with experts, concrete was selected as the material with the most potential. The only challenge was the massive weight. Some further research led to the use of lightweight-concrete, and that opened up the design research to pursue that new direction. At that point Brown developed an initial prototype beehive and production system. The first concrete beehive was similar to the standard wooden Langstroth beehive, with similar wall thickness, chamber design and shape. The intention was to see if, with the same design, the concrete performed better than a wooden hive along the selected beehive design criteria. The beehive and the molding tools were batch produced for intensive field-testing. A group of 5 small-scale farmers and 5 expert beekeepers were selected to make and use the beehives over a season and provide feedback on the system.

He found out that the outcome of the field-testing was positive. The swarms they housed performed exceptionally, outdoing the comparative wooden hives by as much as 200% (measured in honey yield). The production and cost of the concrete beehives was shown to be much easier and cheaper than the wooden versions. In short concrete was shown to achieve higher desirability along most of the criteria when compared to wood or plastic. The data pointed to the potential success of lightweight concrete as a beehive material, given that all of the issues identified during the testing could be solved. These were issues like the slow and difficult molding process due to the complicated steel shutter moulds, or the fragility of the concrete components that were trying to mimic the design of wooden counterparts too closely with sharp corners and thin sections.

Since Townsend (1984, p.1) said that, "Peter Paterson suggested the use of cement hive for the Sudan since it was an available material". The researcher is also convinced that this could as well be used in Uganda since cement is available in every part of the nation. Beegin, *ibid* recorded that Brown discovered that the beehive design criteria highlighted several thematic areas that required improvement such as cost, durability, production speed, ease of production, insulation, harvesting system, pest exclusion and material. The last theme was a fundamental design feature that had an effect on much of the rest of the beehive. He likewise noted that wooden beehives were relatively cheap, but they would not last long, where insulating and protecting the bees from threats required expensive machinery to make properly.

Plastic-foam (polystyrene) were also cheap, but even less-durable than wood, requiring protective paint for UV protection, and while they created good insulation there had been issues with condensation and internal humidity. Composite-plastic beehives were often engineered to solve the humidity issue, but had been found to create electrostatic discharge problems (resulting in absconding swarms), and at the high price these hives carried they would not last long with fires and bears around. The plastic beehives also required specialized manufacture in industrial locations.

CHAPTER THREE

3.0 METHODOLOGY

3.0 Overview

In this chapter, the methodology used to collect data is explained. The chapter explains the design, the study population, sampling procedure, tools and analysis of data that was used to answer the following questions.

- What is the quantity and quality of honey among apiculturists in Sheema District, Western Uganda?
- How can RBH that improve the quantity and quality of honey be designed?
- How can RBH that promotes quality of honey and safety of colonies be produced for apiculturists in Sheema District?

3.1 Research design

To adequately answer the posed research questions, this study used qualitative research which employed case study research design. Flyvbjerg (2006) noted that a case study is a context-dependent, in-depth investigation of a single example of a phenomenon. Elman, Gerring, and Mahoney (2016) concur with that statement that a case study "focuses intensively on a single case" (p. 375) and the case in focus is supposed to be representative for a larger group of cases.

The research was conducted in Sheema District, where Wild Bees Organization in Stema farm was selected. Wild Bees Organization was considered the best case because of the variety of the beehives that were used in apiculture. The diversity of the beehives placed the researcher in a better position to asses comparatively the safety threats of the varied beehives.

The case study research design critically described the various beehives in Sheema District through an objective examination of each independent beehive to ascertain their effectiveness in the quantities of honey produced and their susceptibility to effects of contamination.

3.2 Study area

The research was conducted in Sheema District, where Wild Bees Organization in Stema farm was purposively selected. Wild Bees Organization was considered the best case because of the variety of the beehives that were used in apiculture of which those hives form the sample space of the hives used in Uganda for apiculture. The diversity of the beehives placed the researcher in a better position to asses them comparatively under the same contextual environment. The case study research design critically described the various beehives in Sheema District through an objective examination of each independent beehive.

3.3 Target population

This research was directed to the people living along the cattle corridor of Uganda since that region is characterized by large chunks of grasslands that are used for pastoralism activities yet they are an important supplier of pollen grain that is a raw material used by bees to make honey. Some of the people in the cattle corridor of Uganda also engage in subsistence farming and the crops they grow are also a source of pollen grain. Sheema falls in the cattle corridor but was selected because unlike other parts of the corridor it has organized apiculture farms.

3.4 Study sample

To exhaustively collect sufficient and reliable information, bee keepers in Sheema County were selected as the resource people since that area is well known for bee farming due to its high supply of honey in the national market. The study therefore worked with three respondents who were directly involved in apiculture.

3.5 Research procedure

The researcher sought for an introduction letter from the relevant university authorities. That letter was used to introduce the researcher to Stema farm in Sheema District which belonged to Wild Bees apiculture organization. It introduced the researcher as a student set out to conduct research so that any assistance given to the researcher would be greatly appreciated. The researcher presented that letter to the different respondents so that they could accept to avail the necessary information that the researcher needed.

The researcher then made observations, interviewed the respondents, took notes and made sketches in regard to the existing beehives and how they contributed to the low quality and quantity of honey, which aided the researcher to fulfill the first objective and equip him with the required knowledge to achieve the second objective. After information had been collected, the researcher then got to the drawing board to produce CAD based RBH that provided safety to bee colonies to achieve second objective. The researcher then finally developed a prototype for the RBH with a design manual that would enable the construction of the RBH.

3.6 Sampling techniques

In order to effectively find out the state of quantity and quality of honey among apiculturists in Sheema District, Western Uganda, Stema farm in Sheema District which belongs to Wild Bees apiculture organization was purposively selected. That was attributed to the fact that the farm had variety of beehives ranging from local beehives to modern beehives of which similar beehives are used not only in Sheema District, but also across the entire Nation of Uganda. That would successfully expose the state of quantity and quality of honey harvested among other apiculturists in the region. All the three respondents engaged in this study were not only educated, but also had several years of experience in apiculture hence the information given by them would be reliable.

To design RBH that improve the quantity and quality of honey, various designs were purposively explored through sketching, technical drawing and CADD. Various tools and materials were also used to test the possibilities and challenges of the various designs.

Finally, to produce a prototype of the RBH with a manual for apiculturists did not require any sampling techniques since it was an outcome of studio practice work

3.7 Methods for data collection

In order to analyze the beehives designs; photography, observation, in depth interviews, and studio experimentation were used.

3.7.1 Observation

Observation as a method was very important in verifying the actual conditions under which the bees were installed. That was to ascertain if those living conditions had any contaminating influence on the honey and also if they had a contribution the estimated volumes of honey produced by each of the beehive.

Observation also enabled the researcher prove if the safety threats of the bees and the beehives was contributed by the type of beehives and beehive materials on the ground so as to make a more reliable opinion and avoid incorrect judgment posed by the preconceived background information.

Finally, during the design process of the RBH for apiculturists in Sheema District, observation was a necessity to spot areas of weakness in the design in regard to the challenges that were previously faced by the existing beehives. To successfully collect the desired information through observation, an observation guide was developed and explained in table 2.

3.7.2 Photography

Photography was essential in capturing the type of materials used to construct the existing beehives in Sheema District and also show how some of those materials had yielded to weather effects. It subsequently was able to capture how some of those deteriorating materials of the beehives could have contributed to the contamination of the honey especially during harvesting as discussed in section 4.1.

By photography, the designs of the existing beehives were registered. Those designs showed how the process of accessing the honey was easy for thieves and vandals hence explained why the honey was susceptible to theft. It also indicated how portable the beehives were, owing to their size and especially if unoccupied by a bee colony, hence easily stolen by thieves without much hustle.

Through photography, it was also possible to capture details such as joinery and assembly of components that formed the respective beehives. That knowledge was helpful in informing the researcher on the technical issues involved in constructing those existing beehives thus being in a better position to improve on the existing technology.

Last but not least, photography also became helpful for the researcher to document sources of inspiration, drawings and studio work that was developed in the course of the research. To successfully collect data through photography, a digital camera was employed.

3.7.3 In-depth interview

Interviews became instrumental in understanding the respondents' views, needs, their desires and their approach to apiculture. That was helpful in informing the researcher of the respondents' tastes and preferences hence it made it possible to develop a user-friendly product.

Through the in-depth interviews, the researcher was also able to get information that could have not been directly observed within the period of the research such as the drying off of rivers and swamps during dry seasons as the research was conducted in rainy season. To successfully collect the desirable information, an in-depth interview guide was designed and explained in section 3.9.

3.7.4 Studio experimentation

In order to develop designs of a RBH for apiculturists in Sheema District that would provide improved quality and quantity of honey, as well as prevents theft of honey and destruction of bee colonies, studio experimentation was crucial as the researcher was able to explore a series of designs that addressed the threats posed in apiculture, and after which it became possible to select the most effective design. The designs were generated through sketching, technical drawing and rendering by CADD, check list and library search.

3.8 Tools of data collection

Various tools of data collection were employed to this research in regard to the method of data collection discussed in the previous section above.

3.8.1 In-depth interview guide

In order to get responses for the cause of poor quality and quantity of honey, the insecurity of both the bee colony and the beehives as well as the suggestions on how to produce a better RBH through in-depth interview from the respondents, in-depth interview guide was employed. Tables 1, 2, and 3 shows details of the interview guide.

Table 3.8.1.1: Analyzing the quantity and quality of honey among apiculturists in Sheema District, Western Uganda.

	Information	Importance
a	Types of beehives used and the estimated quantity of honey produced per harvest.	To know the common beehives used and the effectiveness of the quantity of honey they produced.
b	Materials used to make the beehives	To understand the strength of the beehives and if those materials have an effect on the quality of honey.
c	Source of materials used to make the beehives	To ascertain the proximity and availability of the materials used to construct the beehives.
d	Life span of the beehives	To perceive the durability of each type of the beehive.
e	Inspection of the beehives	To comprehend the process involved in inspecting each type of beehive and if it in any way affected the quality of the honey.
f	Preparation of the honey before selling	To understand the hygienic environment under which honey is prepared after harvesting.
g	Storage of honey before selling	To understand the environment under which the honey is kept before selling.
h	Challenges encounter in beekeeping in relation to the beehives	To capture any constraints experienced by the apiculturists who were not observed in the process of answering the previous questions.

Table 3.8.1.2: Developing designs of RBH for apiculturists in Sheema District that will improve the quantity and quality of honey produced.

	Information	Importance
a	Materials preferred for RBH	To understand apiculturist's desired materials that would meet safety requirements.
b	Reasons for preferring the said materials	To know the reason for confidence in the mentioned materials
c	Availability of the preferred materials?	To understand both the availability and accessibility of the preferred materials
d	Solutions to the challenges faced with the current beehives	To develop an understanding on how to provide design solutions to the challenges
e	How could the solutions above be achieved in the RBH	To develop an understanding on how to provide design solutions to the challenges
	Functions to be achieved in the RBH	To understand secondary functions that apiculturists would desire of the RBH to be designed.

Table 3.8.1.3: Production of a prototype of the RBH with a manual for apiculturists.

	Information	Importance
a	What would be your response towards the prototype for the RBH house?	To understand the relevance of the prototype in construction of the RBH.
b	What would be your expectations as far as the design manual for the RBH is concerned?	To provide a manual that will be relevant to the apiculturists

3.8.2 Observation guide

To give extra weight to the answers of both the first and second question using observation, an observation guide was developed. The idea was to enable the researcher tally the findings from the respondents to what was practically observed on the ground so as to check for any irregularities and omissions by the respondents. Tables 4 and 5 show the details of the observation guide.

Table 3.8.2.1: Analyzing the quantity and quality of honey among apiculturists in Sheema District, Western Uganda.

	Information	Reason
1	Types of beehives used for apiculture.	To know the commonly used beehives
2	Materials used to make the beehives.	To find out if there are materials that have not well been exploited for apiculture.
3	How the beehives are kept.	To find out the convenience of the beehive types used.

Table 3.8.2.2: Developing designs of a RBH for apiculturists in Sheema District that will improve the quantity and quality of honey produced.

	Information	Reason
1	Durability threats of the materials used.	To suggest possible alternative materials to be used in the RBH.
2	Safety threats of the beehives.	To suggest new design ideas for overcoming theft in the RBH
3	Challenges of inspecting the beehives.	To suggest possible design solutions of inspecting bees in the RBH
4	Challenges of harvesting the honey.	To suggest possible design solutions of harvesting honey in the RBH.

3.9 Data analysis

The researcher analyzed the data collected by transcribing the oral speeches of the respondents, sketching, studio experimentation, conceptual drawings and working drawings through which the researcher interpreted according to his judgement and the delivered the information in a narrative format.

3.10 Data quality control

An archetype study was carried out by visiting different apiculturists in Sheema District for data collection as a pre-testing of the final interview. The intent of the archetype study was to determine the accuracy, clarity and suitability of the research instruments and to ascertain their validity and reliability. The data in this research was considered reliable because the researcher was able to interview the Director of Wild Bees Apicultural farm (R1) who was learned and had a lot of experience in the matters concerning apiculture. A family member was also interviewed because of her active participation in apiculture (R2). The researcher was also able to interview a worker in the firm who was also directly involved in apiculture and also had his own beehives (R3).

3.11 Ethical considerations

The researcher sought the respondents' consent before administering the interview to them by allowing them to willingly sign the consent form. He also assured the respondents of confidentiality on the information presented on the questionnaires and that the information given by the respondents would not to be used for any other reason except that of education research.

3.12 Limitations

a) One of the respondents switched off the phone on the appointed day of the interview and since then he was avoiding to be interviewed.

b) With the challenge of the corona virus pandemic, it became very difficult for the researcher to be invited in the firm so as to observe the processes involved during harvesting of the honey especially given that it was the peak season, the researcher had wanted to confirm if the volumes harvested from the different types of hives corresponded to the figures that he had been given to him by the respondents during the research and also check the environment under which honey was handled to note the possible contaminating activities of honey.

c) The hiking of fare also frustrated the researcher's efforts to move frequently to the context of the case thus limiting his ability to make more observations by himself.

d) Whereas the researcher had wanted to depict the actual materials of the RBH on the prototype, that effort was hampered by the total lockdown which saw all the high-resolution printers at Nasser Road in Kampala shut down hence the researcher had to improvise alternative materials to finish the prototype.

CHAPTER FOUR

4.0 PRESENTATION OF FINDINGS, INTERPRETATION AND DISCUSSION

4.1 Introduction

This chapter captures the field work conducted in Stema farm, Sheema District. The chapter covers the findings of the objectives and how they were interpreted and used to design the RBH. Ideas generated by the respondents are captured and steps of developing the RBH are covered. The chapter further discusses the entire process from the inception to the end.

4.2 The scene at Stema farm in Sheema District

The researcher undertook the case study research from Stema farm in Sheema District which belong to Wild Bees apiculture organization. Wild Bees apiculture farm presents a serene environment defined by variety of flowering plants ranging from bananas, shrubs to trees and water bodies such as ponds and seasonal streams. Within that context, several beehives of different types were then observed strategically installed in different structures that sheltered them while others laid on the ground with an expectation that someday, they too would have a better place of installation of which some of those that laid on the ground revealed the misery of their weariness as age had caught up with them and did not give them a sense of ever performing their roles as beehives in future.

Figure 4.2.1 The serene environment under which apiculture is conducted in Stema farm in Sheema District. (Plenty of grass, shrubs, banana plantations and flowering trees offer pollen grain which is a raw material for the bees to make honey.

Photo by researcher: 2020

Upon arrival at the Wild Bees apiculture farm, the researcher became interested in first ascertaining the type of beehives that were used for apiculture in that particular case study farm. While still in the process of creating rapport with respondent R1 who is the director of the farm, he introduced me to the farm by noting that;

> In Wild Bees farm, we use the local beehive, we use the Kenya Top Bar and then we use the Langstroth beehives. Those are the three types of beehives we have here. All of them have their advantages and disadvantages.

Those varied types of beehives which were available at Wild Bees farm gave the researcher the advantage of interacting with the varied beehives commonly used in Uganda by apiculturists as observed in the background information in the first chapter and it also provided a good platform of experimentation to establish the differences of procurement costs and the costs of maintenance versus the overall performance in regard to the quantity and quality of honey harvested from each of them under the same context. It therefore became very critical not to withhold any nitty gritty information in regard to the mentioned beehives. The researcher deemed it befitting to unravel the information beginning from the Langstroth beehive which was considered as an international beehive through the Kenya Top bar hive that was regarded to best suit the tropical climate, and finally the local beehive that was counted to be an indigenous beehive in Uganda that could be afforded to apiculturists at almost zero cost.

4.3 The Langstroth beehive

All the respondents observed that the Langstroth beehive was the most productive hive in terms of the volume of honey harvested twice annually. It was the most celebrated beehive by respondent R1 as having the capacity to yield approximately ten liters of honey during its peak which is normally between August and September.

4.3.1 The Design of the Langstroth beehive

The complexity of art and architecture of that type of hive as noted by the respondents was one reason that most of the apiculturists dreaded to locally fabricate it as a way to evade the high costs of procuring it from the vendors in Kampala city even when the major construction material which was timber, was always readily available within the contextual area.

The Langstroth beehive (Figure 4.3.1) consisted of majorly four demountable parts which included the bottom board or base, the brooder, the honey store or super and the cover. The bottom board formed the base of the beehive and had the entrance for the bees to enter and exit the hive, the brooder which was box shaped and housed the queen that laid eggs and also had wooden frames for honey. Thirdly was the store with wooden frames where the bees deposit the honey, and finally the top cover which sheltered the hive from rain and sunshine.

Each frame consisted a fiber of binding wire upon which the bees were to build the honeycomb. The role of the binding wire was to provide support to the honeycomb so that it would not succumb the weight of itself and that of the honey deposited on it. The strength acquired by the honeycomb gave it an advantage during harvesting time because the honey would get extracted from the honeycomb using honey extractors leaving the honeycomb intact on the frame without damage. The honeycomb itself would then be reused by the bees to store honey without having to construct new honeycombs again hence easing the process of making honey. On the bottom side of the upper part of the frame was always a small groove upon which wax was smudged by the apiculturist, and that smudge of the wax was meant to provide a base or foundation upon which the bee should begin to build the honeycomb.

Figure 4.3.1 The different parts of Langstroth beehive
Photo by researcher: 2020

4.3.2 The strength of the Langstroth beehive

respondent R2 commented that the strength of that hive was embedded on the fact that the brooder was separated from the honey store by a wire mesh. She continued to note that, that became very crucial in ensuring purity of the honey harvested from the honey store since the honey store became detached by a wire mesh from the brooder which contained the eggs, larvae and the pupa. She said that the role of the mesh was to prevent the queen bee owing to its big size, from accessing the honey store so that it could lay eggs there. The researcher found that argument to be very interesting as it begun answering the challenge as to why most honey is rejected by the global market because an illiterate apiculturist may never conceive and understand that the queen bee has the capacity to contaminate the honey by her eggs! Last but not least, the high volumes of honey harvested in the Langstroth beehive required an applause and which later inspired the researcher to borrow the concept of the Langstroth frame into the RBH.

Figure 4.3.2 Coffee mesh below the super which excludes the queen bee from the honey store (left) and the frames inside the super upon which the bees construct the honeycombs (right).
Photo by researcher, 2020

4.3.3 The Langstroth beehive materials and their source

The Langstroth beehives were fundamentally made of timber, binding wires, coffee mesh, aluminum sheets and nails. These materials did not easily decay so as to affect the quality of honey. In as much as all those materials seem to be locally available, the design technology involved did not appeal to local fabrication by local carpenters due to lack of necessary carpentry skills that would enable the local carpenters achieve the necessary joinery especially the Langstroth frame itself. Apiculturists were therefore compelled to procure those types of beehives from Kampala City vendors thus incurring extra costs of transportation.

4.3.4 Installation of the Langstroth beehive

In Stema farm, the Langstroth beehives were installed under shrubs. respondent R1 and R3 said that the shrubs provided a cool environment for the bees in Langstroth beehives. respondent R3 further posits that the beauty with those shrubs was that they concealed the hives so that it would not be easy for a stranger (a potential thief or vandal) to notice the beehive. The shrubs themselves formed not only a zone of safety, but also a nucleus of pollen grain therefore some bees would not have to fly longer distance to collect the pollen grain. The shrubs around those beehives also sheltered them from dust hence minimizing the chances of dust in the air contaminating the honey. Although respondent R3 argues that the shrubs enhance the safety of the hives, respondent R1 had assumed that workers themselves steal the honey. However, the safety of those beehives could well apply to the public who may not necessarily have had an opportunity to discover the locations where those beehives were installed

Figure 4.3.3 Installation of the Langstroth beehive under shrubs
Photo by researcher, 2020

4.3.5 Challenges of the Langstroth beehive

The greatest threat with this type of hive was that of termite attack because it was made of wood. However, that challenge was mitigated by the use of anti-termite treatment around its placement or placing the hive in a place that could not be accessed by termites.

Another weakness that was associated with the Langstroth beehive was that of yielding to weather. That weakness manifested in two forms. The first form was that of the wood rotting when frequently exposed to rain while the second was that of wood warping when exposed to sharp temperature gradient. In the attempt to minimize the rotting of wood, the hive was painted and the tops given a water proof lining of aluminum sheets while in the effort to reduce warping, the hives were placed in a shaded shrubby environment.

That hive also suffered the challenge of high cost as R1 noted that each hive costed two hundred thousand Uganda shillings which not many of the apiculturists could afford especially when they needed to procure many of them to boost the quantity of honey produced.

respondent R3 noted with concern that it was also a challenge to harvest honey from the frames if the farmer did not have a honey extractor, therefore the attempt to pull the honeycombs from the binding wires would sometimes result to the damage of the frames

4.4 The Kenya Top Bar (KTB) hive

All respondents agreed that the KTB hive was the most commonly used by apiculturists. In addition to being cheaper than the Langstroth beehive, it gave a fairly good volume of honey. respondent R1 estimated the KTB hive to yield up to six liters of honey per harvest, more so, the hive costed fifty-six thousand Uganda shillings when the apiculturist provided his/her own wood or ninety-eight to one hundred and twenty thousand shillings if bought from the carpenter. The hive was easy to manage and also easy to fabricate.

4.4.1 Design of the KTB beehive

The researcher observed that the KTB beehive consisted of removable wooden top bars over which the combs were built by the bees. Some of these hives were fitted with what respondent R1 called a frame-type feeder and a queen excluder made of coffee wire which consists of 5 mm mesh positioned in between the beehives. Most of the KTB beehives were without the queen excluder hence the queen bee freely laid eggs on the combs which would be harvested to extract honey. Those eggs would be a source of contamination of honey thus hinders its penetration into the market. The researcher appreciated the simplicity of that design for the fact that it could even easily be fabricated locally however; the need to increase the quantity of honey to meet the shortage of honey in the global market did not attract his attention so much to that type of the beehive.

Figure 4.4.1 KTB beehive (The wood succumbs to weather creating openings between the joints hence giving way to intruders.)
Photo by researcher,2020

4.4.2 The strength of the KTB beehive

All the respondents argued that the KTB hive was not only found to be easy to fabricate locally by carpenters, but was also easy to inspect, maintain and service. The fact that it was possible to incorporate the queen excluder into this hive, it gained equally the advantage of harnessing honey that was free from the eggs, larvae and pupa hence the possibility of observing good quality honey. The KTB hive was also considered to be cost effective and economically friendly although it did not yield better than the Langstroth beehive.

respondent R1 noted that the lifespan of the KTB beehive was quite longer because he had used them for five years and they had not been affected so much by the weather since they were under a shelter and so he thought that they would go between ten to twelve years of use. But he also noted that those KTB hives that he had kept outside lasted for only four years because of the weather conditions and that is why he decided to construct for them a shelter so that they may not be affected by too much rain or sunshine. The researcher therefore noted the need to protect the hives from weather so as to increase their lifespan.

4.4.3 KTB beehive materials and their sources

Timber and nails were the basic materials that were used to make that type of hive. When one wished to exclude the queen bee, then coffee mesh was incorporated in between the hive. The top of the hive was covered by material such as iron sheets which kept rain from entering the beehive. Due to the simple technology of this beehive coupled with local availability of timber within Sheema District, the respondents found it very economical to make this hive locally so as to make more savings to the cost of procuring ready-made KTB hives from vendors in Kampala.

Figure 4.4.2 different materials such as trees, grass and reeds that are used to make the beehives in Wild Bees farm.
Photo by author, 2020

4.4.4 Installation of the KTB beehive

Owing to the large numbers of the KTB hives in the farm (sixty), it was considered necessary to contain them in a focal place for easy provision of security, management, inspection and harvesting of honey. That called for construction of a semi-permanent shelter which housed the KTB hives. That structure also contained about ten local beehives. When respondent R1 was questioned regarding the challenge of theft, this is what he had to say in regard to that semi-permanent shelter;

> One of the reasons I put the hives in the house is that I wanted to have control who enters my hives. Originally my own workers would find their ways in and do the harvesting when am not even around! I would come and when am checking I discover that someone had taken the honey from the hives. So, the best thing to do was to lock the place up, for the bees, they can get out through the mesh, they can move out and come back in but the human beings we closed them out.

> Another thing is we could be having lockable beehives so that you lock and number your beehives and say that this key is for number seventeen, this one is for fifteen, this one is for, like that. You lock them up and put them in strategic places so that you don't miss out some production. So, it is important to have a lockable beehive so that you have control so that even if you are not there, no one will tamper and steal your honey.

The construction of the shelter involved the use of wooden piles which were then covered with timber off-cuts and wire mesh on the sides as shown in figure 4.4.3. The shelter was roofed with iron sheets to keep off direct sunlight and rain. Some level of security was increased in the shelter by having a lockable entrance in to the shelter. Within the shelter was two level of timber platforms on which the beehives were placed for support. Though the shelter looked functional, space wastage was observed as there were unnecessary large walkway in the shelter and the gaps between the beehive platforms being unnecessarily wide. The KTB beehives were free from contaminants such as dust or dirty storm water. Whereas the KTB beehives in that shelter was free from thieves, the honey was not spared by rodents such as rats which were found residing in one of the empty beehives during inspection by the researcher.

Figure 4.4.3 lockable structure where the KTB beehives are installed
Photo by researcher, 2020

Figure 4.4.4 the lockable entrance (left) and the interior space planning of the lockable structure exhibiting extravagant use of space.
Photo by researcher, 2020

4.4.5 Challenges of the KTB hives

respondent R3 observed that the KTB beehive faced several challenges which included the breakage of the combs from the top bars either during inspection of the beehives or transportation of the beehives. He continued to note that the breaking of the honeycomb affected the development of honey hence compromising the volume of honey that was harvested. That necessitated great care to ensure that the combs were maintained in a vertical alignment during the handling of the top bars.

The challenge of weather was also of great essence since the wooden structure of the KBT beehive yielded by cracking and warping to sharp temperature gradients and paved way for rodents such as rats. This effect was however minimized by placing those KTB hives in shaded places.

Rotting of the beehive though not severe was associated with rain or high moisture content in the atmosphere was also a challenge not to disregard as echoed by both respondents R2 and R3 who attributed it to windy storms.

Figure 4.4.5 How the honeycomb gets attached to the wooden bar (left) and how the wood yields to weather (right).
Photo by researcher, 2020

Whereas the KTB hive had been praised for its simplicity and effectiveness by all the respondents, respondent R1 surprisingly claimed that it was cumbersome to harvest honey from those beehives both KTB and Langstroth beehive. He pointed that it would be helpful if the researcher came up with an appropriate technology for harvesting honey. The researcher later noticed that that respondent Ra had preconceived ideas of the Flow hive which the researcher suspected that he had not yet perceived the mechanical and technological challenges of the flow hive as well as its financial implication.

4.5 The Local beehive

The Local beehives were fundamentally made of papyrus, reed, banana leaves and cow dung. All the respondents considered it as the cheapest beehive one could make for themselves locally sometimes even without cost implications as noted by respondent R2.

Despite the fact that the local beehive was cheap, it offered the least volume of honey harvested as the respondent R1 estimated it to be two liters of honey for the peak harvest

4.5.1 Design of the Local beehive

When R1 was asked on how the local beehive in the farm was constructed, this is what he had to say;

> For the local beehive, we normally use papyrus, reeds which are locally available in the swamps around, and then we weave it together with fiber and put cow dung on top of it so that wind does not go inside of the beehive.

Besides the fact that that beehive design involved the use of papyrus reeds woven together with fiber to form a basket like hollow form where the bees would have to build the honeycomb within its internal surface, it also consisted of an open end which allowed for inspection and harvesting of honey.

In as much as the basket was coated with cow dung finish which not only closed up the small gaps between the papyrus reeds to prevent wind from blowing in, but also acted as water proof membrane to keep the hive free from rain, that did not completely keep the rain off the honeycombs but just minimized the absorption of the contaminated rainwater into the beehive. Moreover, the cow dung soon exfoliated under the effect of the sun thus exposing the hive to a greater challenge of intrusion of contaminated rainwater.

The closed end of the beehive consisted of small openings that served as the entrance for the bees into and out of the hive. The open end of the hive was closed with a papyrus ring wrapped with banana fibers to form a disc shaped lid. That lid was openable and allowed for inspection of the beehive and also harvesting of honey.

Figure 4.5.1 The local beehive and the materials used to construct the hive
Photo by researcher, 2020

4.4.2 The strength of the local beehive

Since that hive was achieved typically based on locally available materials within the context, the respondents agreed that the hive became the most affordable to any apiculturist who wished to keep bees with very little or no financial implications. That would make it affordable even to the poorest apiculturist in the entire community as emphasized by respondent R2.

4.4.3 Local beehive materials and sources

The presence of swamps in the context became the hub of the papyrus which was the raw material for that hive. Grass was a plenty raw material while cow dung was a byproduct of cattle keeping that also took place within that farm. That explains why the R2 said that for the local beehives, they were locally available and that they got them from the swamps around and used them to make the local beehives!

That explained why the Local beehive was the most easily affordable beehive that any interested apiculturist even without a strong financial ability would choose to have.

4.4.4 Installation of the Local beehive

Some of the local hives were spotted just laid on the ground. That was probably due to the fact that less value was attached to those type of beehives.

A few of them were seen to have been mounted on small shelters. The shelter consisted of four piles of wood with a platform over which the local beehive was set and it protected the hive from rodents. The piles were roofed to protect the beehive from direct sunlight and rain. respondent R1 noted that the wooden piles would always rot at the sub structure and within a year or two, the shelter would be on its way to collapse on account of the weight of the beehive and the super structure itself. Whereas that type of shelter had a roof, the beehive was never completely protected from the effects of weather, hence the beehive would be noticed to be yielding to the effects of weather and the life span of such a shelter was never spared by weather.

Figure 4.5.2 the Local beehive steadily being supported by the shelter (Left). The shelter steadily yielding to the weight of the local beehive (Right)
Photo by researcher, 2020

That type of beehive was exposed to the public and always attracted thieves and vandals due to the simplicity of the ability to steal honey from it.

Another type of shelter for the local beehives was also seen in the farm. That shelter was an attempt to try and host multiple local beehives so as to cut the overall cost of keeping many local beehives on each independent shelters. It involved erecting multiple wooden piles in a linear manner such that a longer platform would be constructed on them. Unfortunately, that shelter did not last long due to incapacity to carry many hives and the accelerated rate at which the lattice decomposed due to rain according to respondent R1.

Figure 4.5.3 The wooden lattice frames on which the local hives were installed succumbed to weather
Photo by researcher, 2020

4.4.5 Challenges of the Local beehive

According to the respondent R1, the local beehive had the shortest life span due to the faster degradable nature of the materials that were used to construct it. The cow dung easily got eroded by rain and exfoliated from the papyrus reeds therefore exposing the interior of the hive to impurities such as contaminated rain water and dust particles. That hive could only be used as much as two harvests of honey which amounted to life span of about one year when the hive was kept under a shelter and one harvest amounting to six months if it was exposed to the weather, beyond that the bees would begin to vacate and abscond from the hives.

It was also a challenge to harvest honey from that beehive since it resulted to destruction of bee colony as the combs were pulled from its walls and contamination of honey by the fragments of particles that disintegrated from the hive itself. That challenge was a threat to delivery of honey harvested from such hives to the formal market because of impurities therefore the honey would only be sold to the informal market.

Figure 4.5.4 The local beehive installed in the shelter (left) and the local beehive expossed to weather (right)
Photo by researcher, 2020

4.5 Inspection of the beehives

Inspection of the beehive being one of the prerequisites in apiculture, respondent R1, when interrogated on this subject responded as follows;

> How I inspect my beehive is that I do inspection once a month. I use the smoker and my brush, and open the hive and chase away the pests that are in there. The pests include spiders, wasps, it includes spiders, wasps, rats. They all disrupt the bees!
>
> You must inspect your beehive to be sure that the bees are in, and chase away some of the rodents that are in. You saw an example when we opened one and the rodents were moving out. So, you need to do a monthly check up and make sure they do not set up nests there, and make sure the weather is not affecting the bees, there is no leakage. Once the bees detect that there is a leakage, they will move out and find another safe place.

From that response, it was observed that keeping away pests is one of the necessary requirements if an apiculturist is to observe better quantities of honey. It was therefore important to ensure a design innovation that would do better in keeping away some of the pests. Rats for instance, could have been kept away if there was limited access to the beehives. The beehives should be flexible such that one could easily access the possible hiding places for pests such as spiders and wasps. Weather, especially rain being one of the reasons bees can choose to swarm and also be a source of contamination of honey necessitated that the RBH innovation kept rain off completely from the beehives.

4.6 Caution of the bees

While the bees are very beneficial insects, they require maximum caution as they may prove to be the most dangerous insects not just to humans but also to birds and animals. While interviewing respondent R2, she had the following interesting experience to give;

> One day my brother collected rubbish and then set it on fire. Of course, my mum and dad had gone to work as usual. After some time, we begun to see a swum of bees moving around in the sky, so we thought that the bees had come to occupy a beehive. 'Kumbe' haaa! ehe ehe! (As she giggled). All over a sudden we begun to see the goats scattering in the compound! Ehe ehe! (She continues to giggle), The chicken also begun to run left and right! The cows were stranded on the ropes! 'Ashaaa'! The bees had attacked them and we knew that trouble had arrived! We also had to take off into the house! So, my brother took my mummy's *'kitenge'* (An African fabric), covered himself and went to untie the cows so that they could run for their lives! You can imagine evening arrived and the animals had not yet returned! We were troubled and did not know what to tell our parents…

The respondent's brother had no intentions of antagonizing the bees instead he was just involving himself in home chores of cleaning. Having collected a few garbage, he opted to burn them. He never had the conscience that that would have an impact on the bees as the beehives were not very close to the garbage he had set on fire! When the smoke dispersed into the atmosphere and reached the beehives, they became furious and provoked to attack anything on their way. That was an eye opener, that any activity that involves smoke should never be conducted anywhere near the RBH as one would not be able to envisage the kind of damage that would be caused by the vast number of the bees expected to be in the RBH.

While at Wild bees farm the researcher was concerned because he observed poultry houses just near the beehives and thought that that must be very risky. When respondent R1 was asked on the matter of safety of the birds especially after harvesting honey, he said that the harvesting was normally done at night so by the time morning arrived, the bees were always confused and they had no idea who had taken the honey from them!

Figure 4.6.1 Beehives' shelter (Left) and poultry houses (Right). In between are a few local hives installed in this site.
Photo by researcher, 2020

4.7 Preparing the honey after harvesting

Once the honey was harvested, it was then carried a way to an isolated room where it was extracted from honeycombs. According to the respondent R1, the crude honey always contained impurities such as bees, bee parts and other foreign materials that may have unintentionally found their way in. The respondents sieved the honey after extracting it from the honeycombs to eliminate some impurities. When respondent R1 was asked how he prepares his honey before selling, he gave the following feedback;

> Aaah! The honey before selling, I usually at harvest time go with a bucket, I cut the combs, and they fall into the buckets, now, those buckets are opened and sieved. I just put them on a sieve. I do not press, I do not boil, I do not do anything else, let the honey just come out by itself. It just drips out

> through the sieve and into another empty bucket, and then I use the settling tank and then package in smaller quantities which I sell to Kampala, I do other things with the wax.

Whereas respondent R1 gave the above procedure of handling honey before selling, there are a few more observation that were made by the researcher. First of all, the researcher noted that the cutting of the honeycomb was only applicable to the event that the honey was being harvested from the local beehive or the KTB beehive. For the Langstroth beehive, the honey was obtained by extracting it from the Langstroth frames using an extractor as the honeycombs were firmly attached to the binding wire that was a component of the frame.

It was also observed that honey collected from the KTB and local hives registered more impurities as the honey had to sometimes be manually squeezed from the honeycombs to maximize the outcome which exposed the honey to impurities due to this handling process contrary to what respondent R1 had expressed. After extraction, the honey was then filtered and packaged.

Honey that was collected from the Langstroth beehives had improved quality as the respondents had extractors to extract the honey. The extractors worked on the principle of centrifugal force where several Langstroth fames were loaded on a manual wheel that spanned about a central axis allowing honey to flow freely from the combs and get collected at the bottom of the extractor then flowed out through an outlet tap. After the honey was collected, it was filtered and packaged.

The researcher also noted that respondent R1 made a sweeping statement when at one time he said that he does not squeeze honey from the honeycombs yet a careful observation of the byproduct revealed an effort to squeeze the combs! The researcher was therefore left to imagine that probably honey squeezed from the combs could have probably for domestic consumption or for the informal market.

It is important to note that respondent R3 did not have a set apart space for performing the extraction activity as respondent R1 hence he had to do it from his house hence exposing the honey to more threat of contamination through transportation process especially in the event that the weather was rainy or dusty. Children also were potential threat of contamination honey as they would playfully mishandle the honey in the event that they got exposed to it. Besides that, he did not also have equipment such as an extractor. The respondent was just not conscious about the need for quality hence did not uphold high levels of cleanliness.

It is very important to also note that R1 packaged honey that was harvested from a settling tank into different packages such as 250 millimeters, one liter, three liters and five liters which he sold to different people.

Figure 4.7.1 Showing wax that has been been sorted from honey (left) and commercial products made from the wax (right).
Photo by researcher, 2020

4.8 Developing designs of RBH for apiculturists in Sheema District to improve the quantity and quality of honey harvested.

4.8.0 Introduction

The Interior Design Legislative Coalition of Pennsylvania (IDLCPA n.d.), noted that Interior Design is a multifarious profession in which creative and technical solutions are applied within a structure to achieve a built interior environment and that those solutions have to be functional, enhance the quality of life of the occupants (bees and apiculturists). The designs are created in response to and coordinated with the building shell, and acknowledge the physical location and context of the project. Designs should also encourage the principles of environmental sustainability. The researcher therefore became conscious that if he was to successfully engage in the RBH design as an interior designer, then he would be confronted with the major challenge of not just solving the intentions of apiculturists but also ensure that the RBH met the desired quality of life for the occupants who in this case included the bees themselves as well as the apiculturists.

With that background, the researcher having collected the feedback from the questions on objective two of the interview schedule, he went to studio and begun working on studio experimentation to develop a product that would respond to the questions and solutions therein.

Sketching as a tool was used by the researcher to explore the sources of inspiration so that conceptual design of the RBH could begin. Because of the need for apiculturists to have multiple beehives, the researcher considered it necessary at the preliminary stage to begin generating forms that could maximize space by having as many hives as possible and also at the same time being conscious of the findings from objective one.

After the sketches were developed, they were comparatively analyzed by the researcher, and that ended up into selection of the best-done sketch which was then subjected to Computer Aided Design (CAD) so as to create an illusion of the final design of the RBH and finally resulted to the development of working drawings.

4.8.1 The bees are 'beautiful people'.

From section 1.9, it was noted that the Contextual Design Theory called for an understanding of the users of the product in order to find out their fundamental intents, desires, and drivers. It became interesting to note that whereas almost everybody would assume that the users of the beehives were apiculturists only, it becomes exciting to note that the immediate users of the beehives were the bees themselves! Despite the fact that the bees could not be interviewed so as to obtain their safety desires, through observation and photography, the researcher was able to come up with intreating findings about the bees that was worth to analyze in order to prepare him to design a better RBH.

It was observed that the worker bee had massive hind legs compared to the rest of the legs as shown in figure 4.8.1. The researcher attributed that to the fact that those legs were responsible for jumpstarting the bee during takeoff as illustrated in figure 4.8.2 which required a lot more of momentum. They were also responsible for carrying the pollen grain from the field hence required more strength as compared to say the fore legs which were actively used as shock absorbers during landing as shown in figure 4.8.3. The takeoff and the landing of the bees was helpful in designing the entrance of the RBH so as to keep away crawling predators such as rats and lizards.

The worker bee constructs cells as shown in figure 4.8.4, in which she would later deposit honey. In those cells, the queen bee lays eggs which develop into adult bees through a process shown in figure 4.8.5. From figure 4.8.6 it was noted that the queen had a bigger diameter than the rest of the bees. It therefore implied that it would be possible to separate the queen using a two-millimeter-wide wire mesh so that the queen does not have to lay eggs where the worker bees would deposit honey to be harvested by an apiculturist and that would help reduce the contamination of honey by the queen bee eggs.

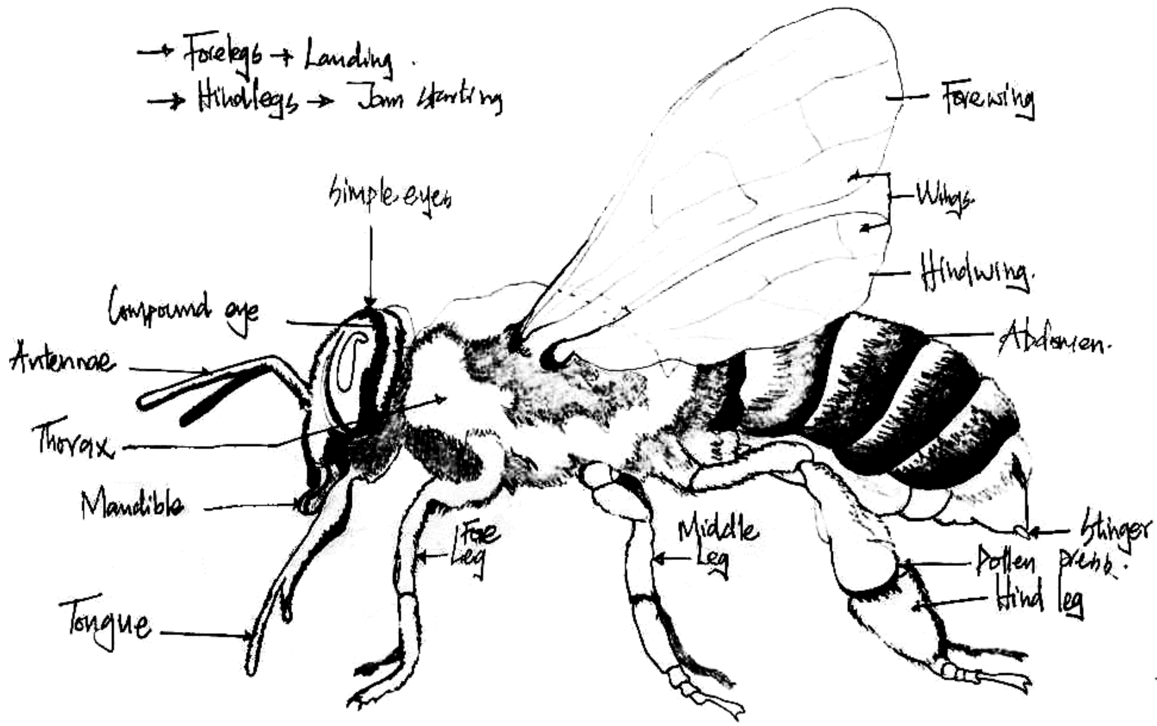


Figure 4.8.1 The massive nature of the hind legs of the bee.
Illustration by researcher, 2020

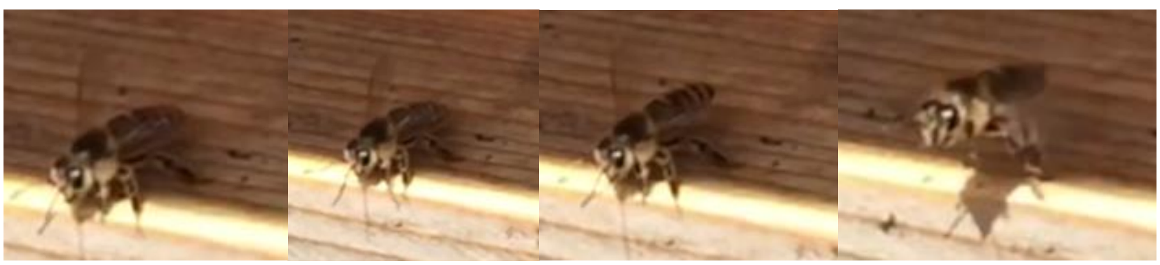


Figure 4.8.2 Motion of the bee at Takeoff: Powerful muscular hind legs responsible for jumpstarting the bee during takeoff.
Photo by researcher, 2020

Figure 4.8.3 Motion at Landing: Fore legs act as shock absorbers
Photo by researcher, 2020

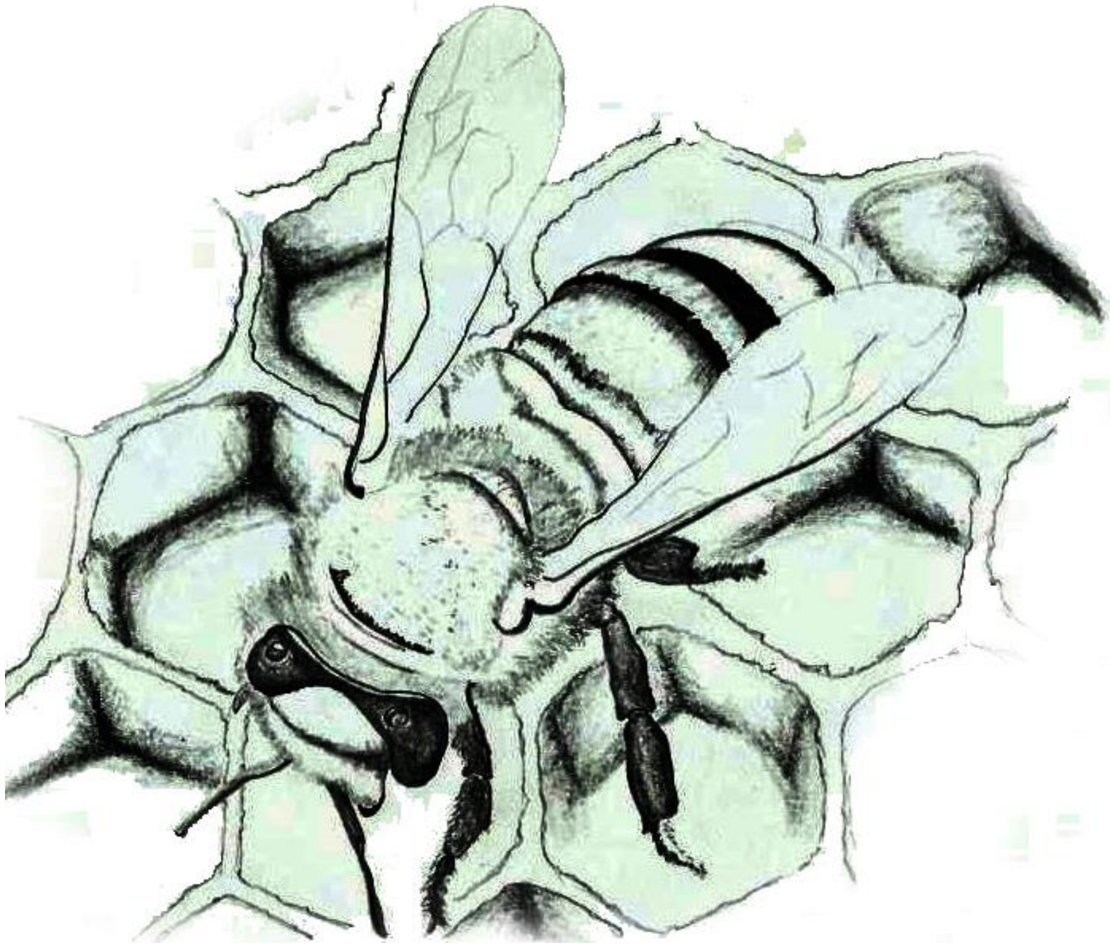


Figure 4.8.4 How the worker bee constructs her cell in which to deposit honey
Illustration by researcher, 2020

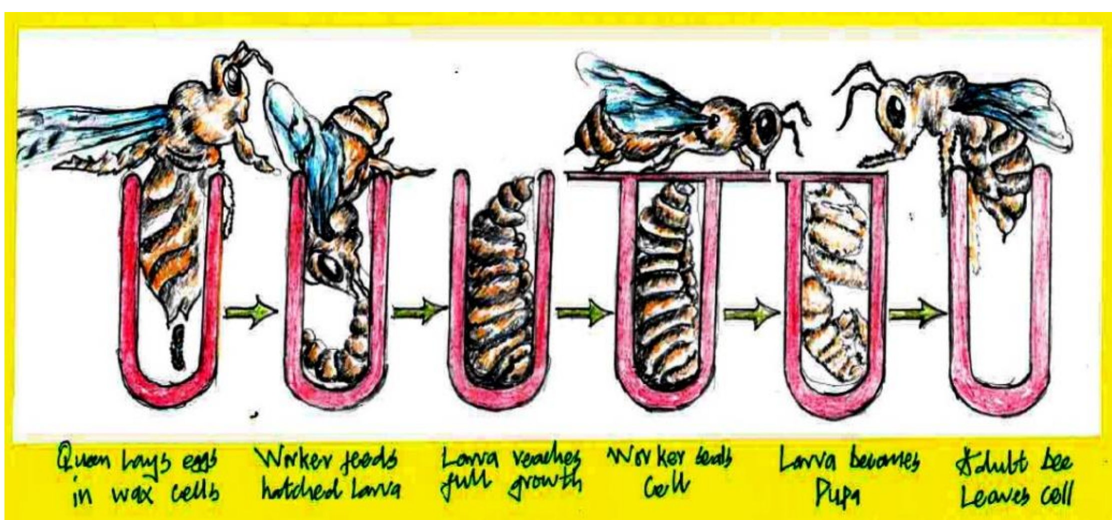


Figure 4.8.5 The process the bee undergoes from the time the queen lays the egg in the cell.
Illustration by researcher, 2020

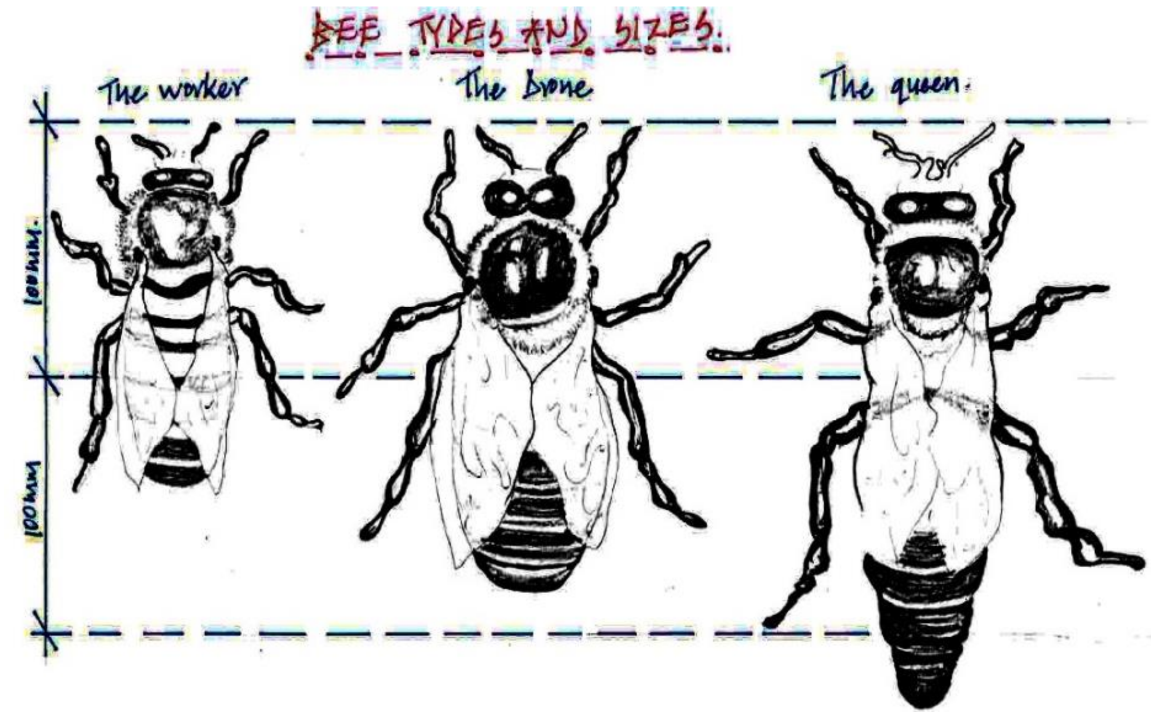


Figure 4.8.6 the sizes of the of the different types of bees relative to each other
Illustration by researcher, 2020

4.8.2 Design 1

The concept of this RBH was to raise the hives above the heights of thieves and vandals so as to frustrate their efforts to steal the honey or vandalize the beehive in the process of stealing the honey. It was also aimed at anchoring the RBH into the ground in a manner so as to so make it difficult for thieves to steal the hives. Heightening the hives on a support would also be effective in precluding intruders such as rats and snakes which frequently would predate on the honey.

The RBH therefore would consist a light weight concrete shell and a pole both casted as structural components. The precast light concrete shell would provide the beehive space which would be enclosed by wood both on the upper side of the opening and the lower side of the opening while the precast concrete pillar would then be anchored in the ground to tower the hives up in the space while ensuring the firmness of the RBH. The light weight precast concrete shell which does not easily yield to weather would also provide shelter to the beehives embedded on it.

The selective materials used in this RBH would be friendly to the bees since they are nature related materials and none of them would pose a contaminating influence to the bees as they don't easily disintegrate into minute particles that would find their way into the honey.

4.8.2.1 Source of inspiration

This design was inspired by the symmetry of the hexagon shape of the cell in the honeycomb. The fact that those cells successfully stored honey gave the researcher the feeling that a RBH designed with that concept would give the public the literal connection and bond with honey they love.

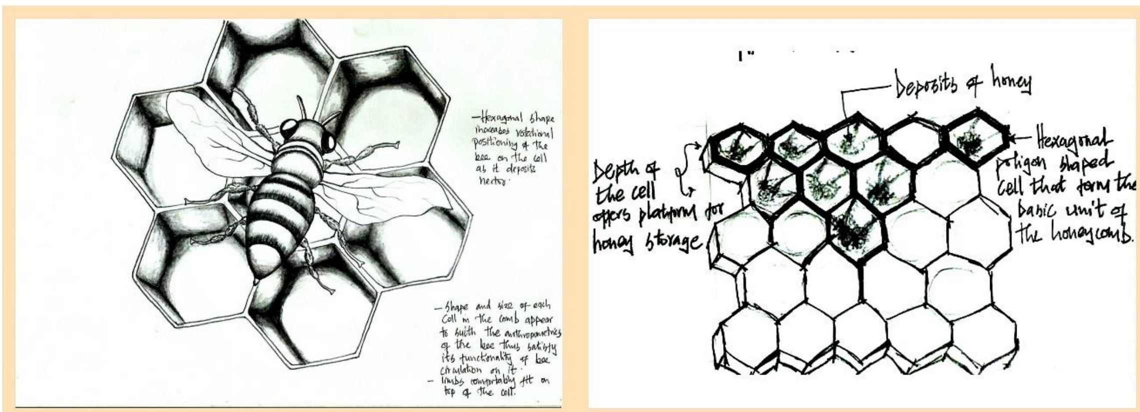


Figure 4.8.7 The honeycomb cells as the source of inspiration of the RBH
Illustration by researcher, 2019

4.8.2.2 Conceptual design

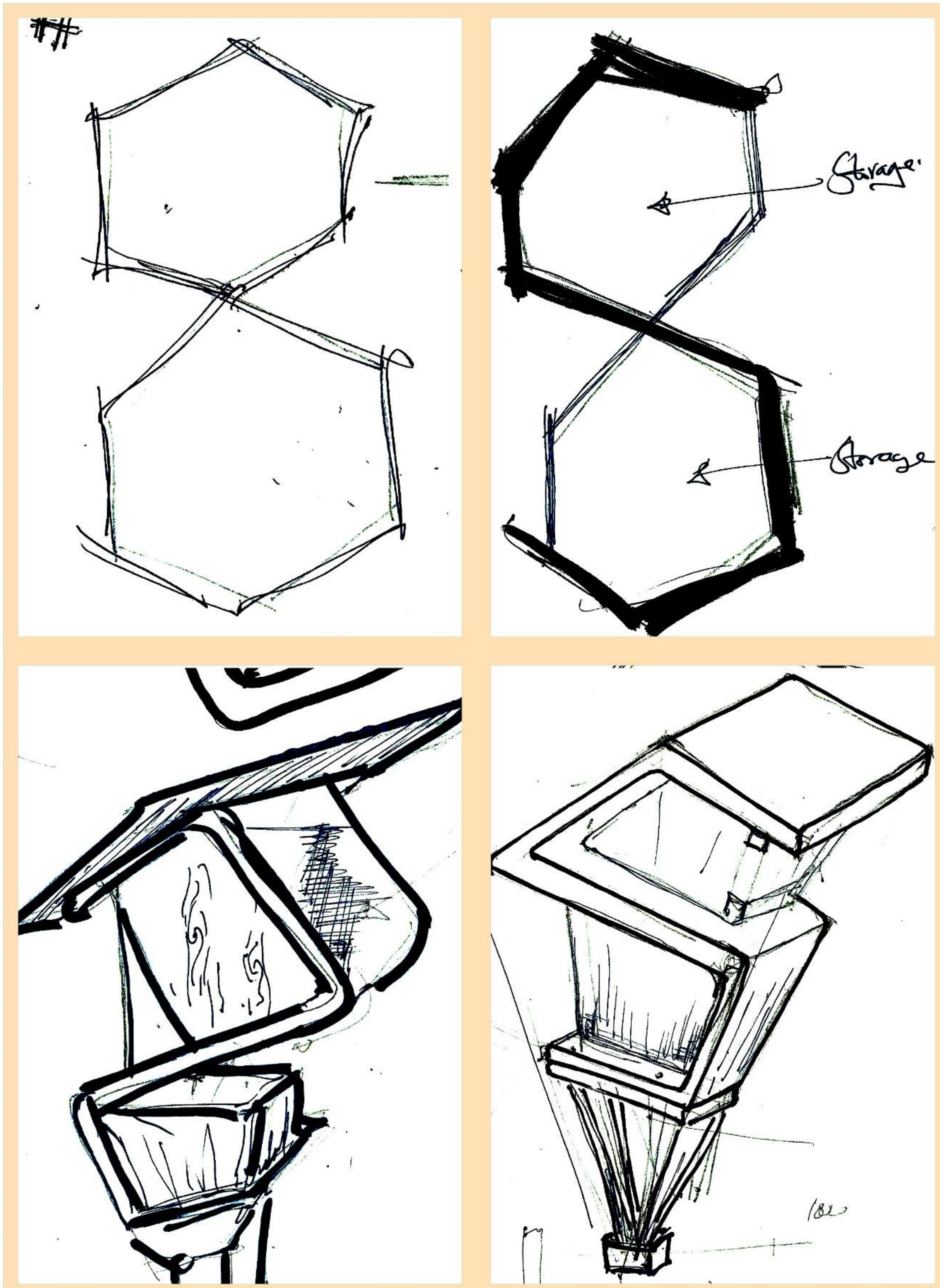


Figure 4.8.8 Idea generation from the hexagon of the honeycomb cell
Illustration by researcher, 2020

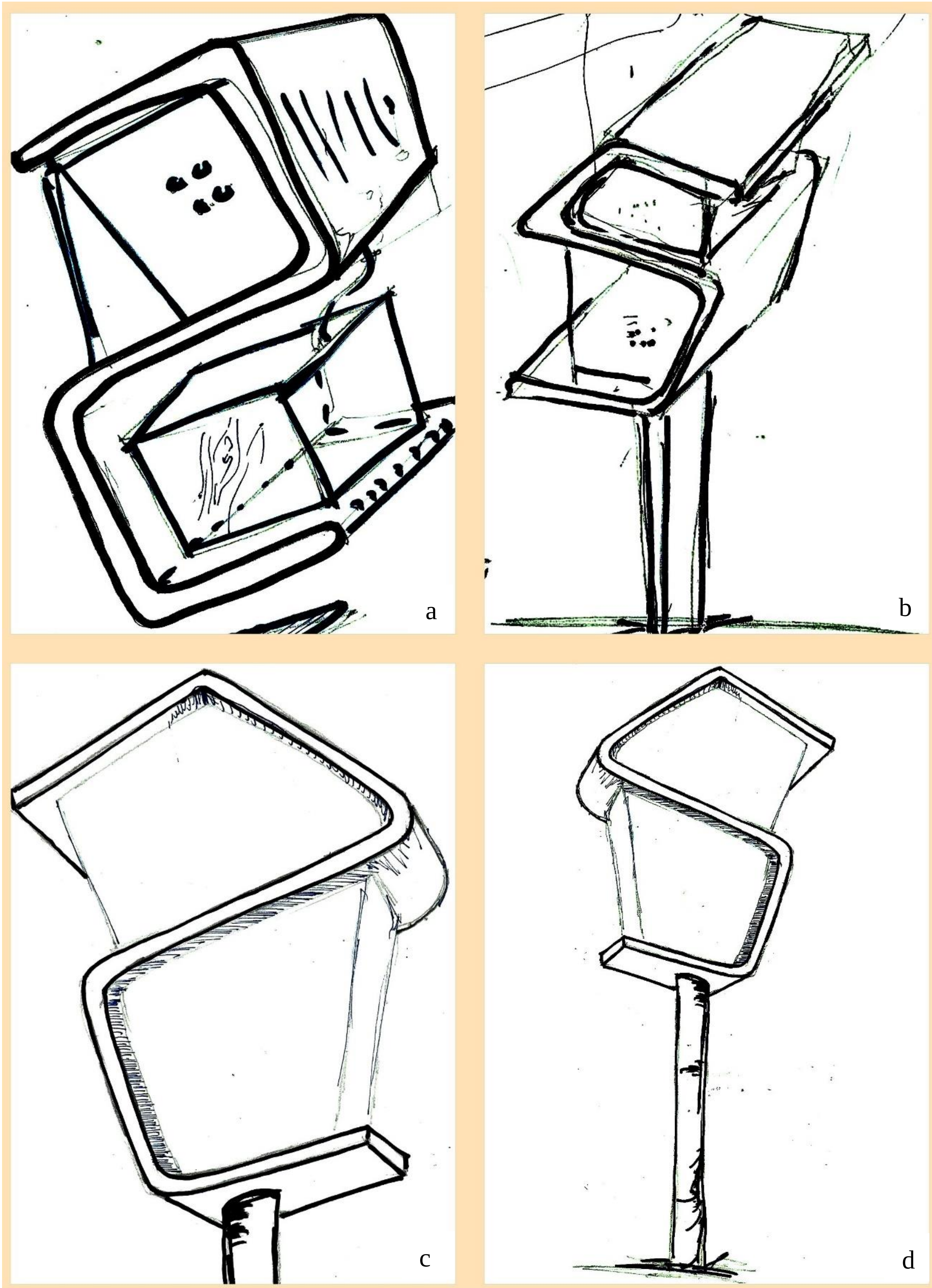


Figure 4.8.10 Development of ideas for the RBH form the honeycomb cell
Illustration by researcher, 2020

4.8.2.3 Visualization

Figure 4.8.113D views impression of the RBH installed on the ground.
Illustration by researcher, 2020

4.8.2.4 Challenges of the RBH

Whereas this type of RBH appeared safe and strong, it was accompanied by some challenges. The first one being the complex shape of the reinforced concrete shell which would require complex mold design to cast them. That would be very challenging to apiculturists as they may not be having skills to fabricate such molds.

The fact that both the shell and the pole would have to be reinforced with BRC mesh posed a cost challenge as the mesh is expensive and would inflate the overall cost of acquiring this type of RBH yet most apiculturists are keen about the cost of beehives in respect to the outcome in terms of profits.

Despite the fact that safety was achieved by the heights, it would be very challenging to inspect the RBH and harvest honey as one must have a three-stand ladder to get to the hives which could also pose another challenge of toppling in the process of inspecting or harvesting honey and would be operose in the event that there are many RBHs to be attended to.

In as much as this design attempted to address the first and second objective to a greater extent, the challenges observed, which are literally extrinsic to the objectives, the researcher deemed this design not to be a successful product for the apiculturists.

4.8.3 Design 2

In this design, the researcher became more driven by the need to increase beehives in the RBH so as to increase volume of honey produced from each RBH hence to maximizing profits that would be obtained by apiculturists as opposed to having only two hives in a single RBH as seen in section 3.10.3, which would require installation of multiple RBHs that will make the overall cost of apiculture expensive. The researcher was also lured to explore earth materials such as grass and soil in this design with an aim of reducing the cost of construction of this RBH since these materials would be freely available.

Safety of the hives and honey would be attained by having them accessed internally through a lockable entrance. The bees would then have their entrance externally while the inspection and harvesting of honey would be done internally.

Having analyzed the design, the researcher thought it much better to harness storm water from the roof so that it could be used to serve the bees during times of scarcity and also for cleaning the RBH. That led to the replacement of the grass thatch with iron sheets that would effectively collect storm water. The RBH would then have to be furnished with an external water tank that would store the water. That water tank would have to be fed by a gutter that runs around along the edge of the roof, and it would also have to be elevated by having an earth base below it. A shallow cemented platform would then be made on that base to contain water that would in turn serve the bees.

4.8.3.1 Source of inspiration

The form of the design was inspired by an online local beehive which was made of grass thatch on a tree trunk that hosted bees. From the researcher's point of view, that design should have been adopted to blend in with the neighborhood which was essentially of grass thatched huts as illustrated in figure 4.8.12.

The design was also inspired by the geometry of the hexagon cells in the honeycomb. That geometry was translated into the plan of the RBH as shown in figure 4.8.15. That hexagon layout of the walls would give room to align multiple hives all-round each independent wall where in this case each wall accommodated two beehives.

Figure 4.8.12 a local beehive made of a hollow tree trunk and covered with grass thatch
Source: https://www.google.com/search?q=ANCIENT+BEE+HIVES&client=firefox-b&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjTt8jG4PveAhVJsKQKHequAWkQ_AUIDigB&biw=1366&bih=632
Year: 2019

4.8.3.2 Conceptual design

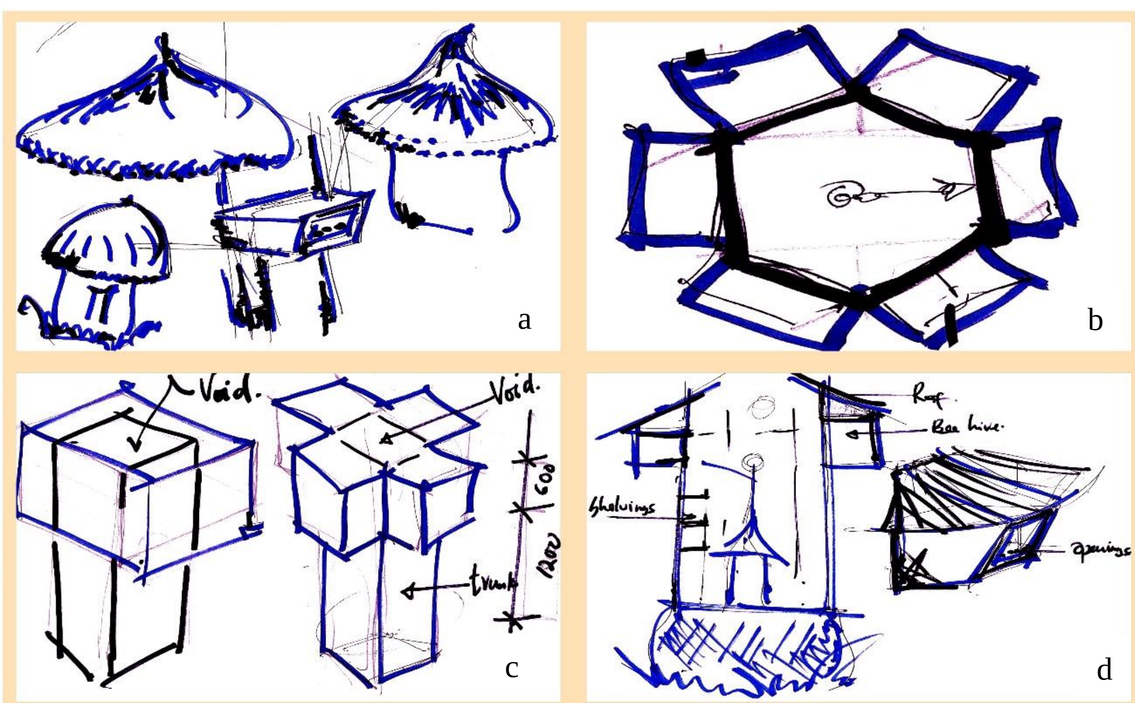


Figure 4.8.14 Sketches a, b, c and d which describe the thought process of the design
Illustration by researcher, 2020

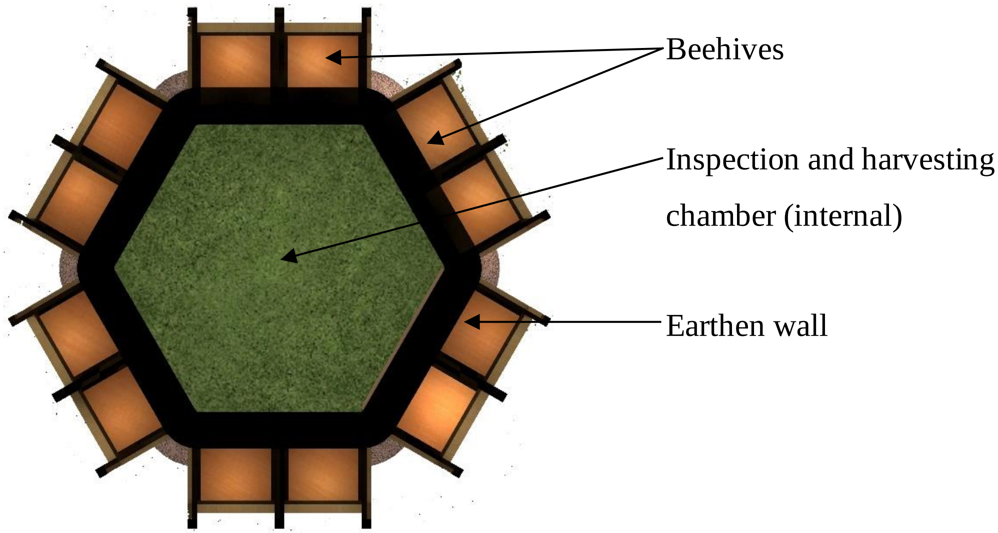


Figure 4.8.15 The radial layout of the beehives around the RBH
Illustration by researcher, 2020

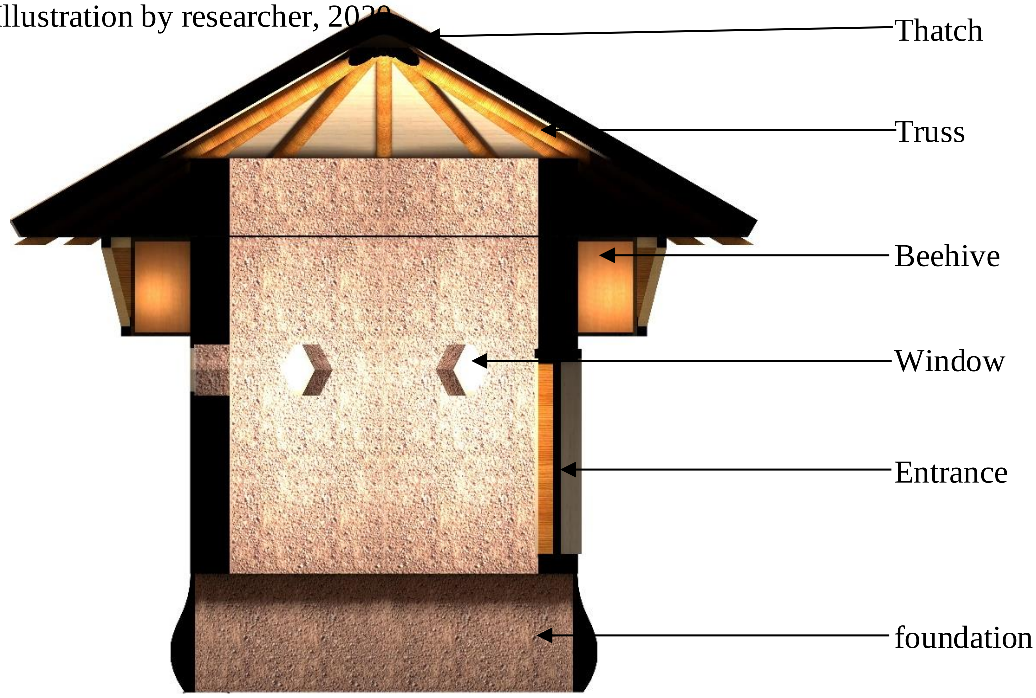


Figure 4.8.17 a cross- section through the RBH to capture the internal details
Illustration by researcher, 2020

Figure 4.8.18 How beehives are mounted on the external view of the RBH
Illustration by researcher, 2020

4.8.3.3 Visualization

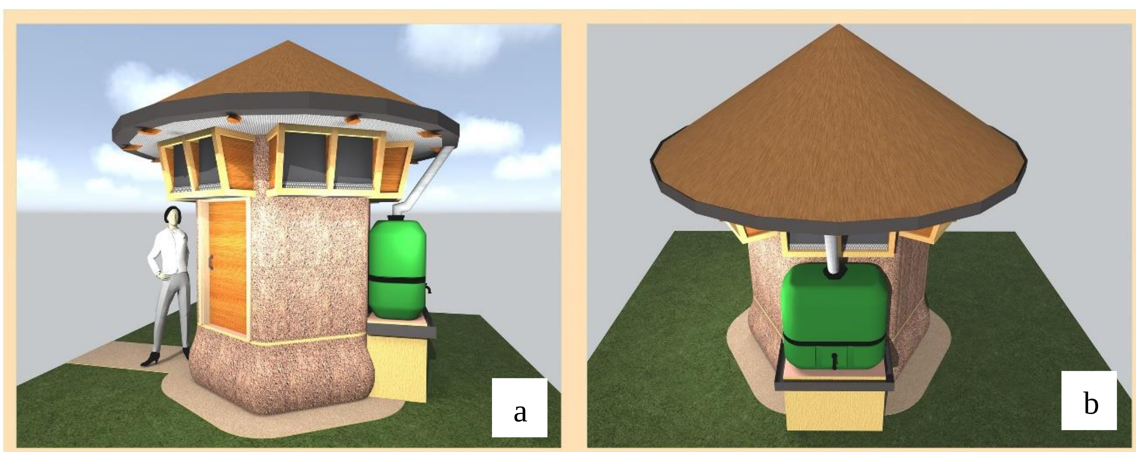


Figure 4.8.19 side view of the RBH (a) and the rear view of the RBH. (b)
Illustration by researcher, 2020

The researcher went ahead to construct a model which showed the structural members of the RBH. Figure 2.8.22a, shows the initial steps of reinforcing the joints with a masking tape to allow them attain firmness as the glue took its time to harden the joints, b, shows the horizontal members which in reality would be responsible for holding the earth to form a stable wall, c, shows how the concept of hexagon was captured in the plan while d, shows the development of the structural model.

Figure 4.8.22 The process of constructing a structural model of the RBH
Photo by researcher, 2020

4.8.3.4 Working drawings.

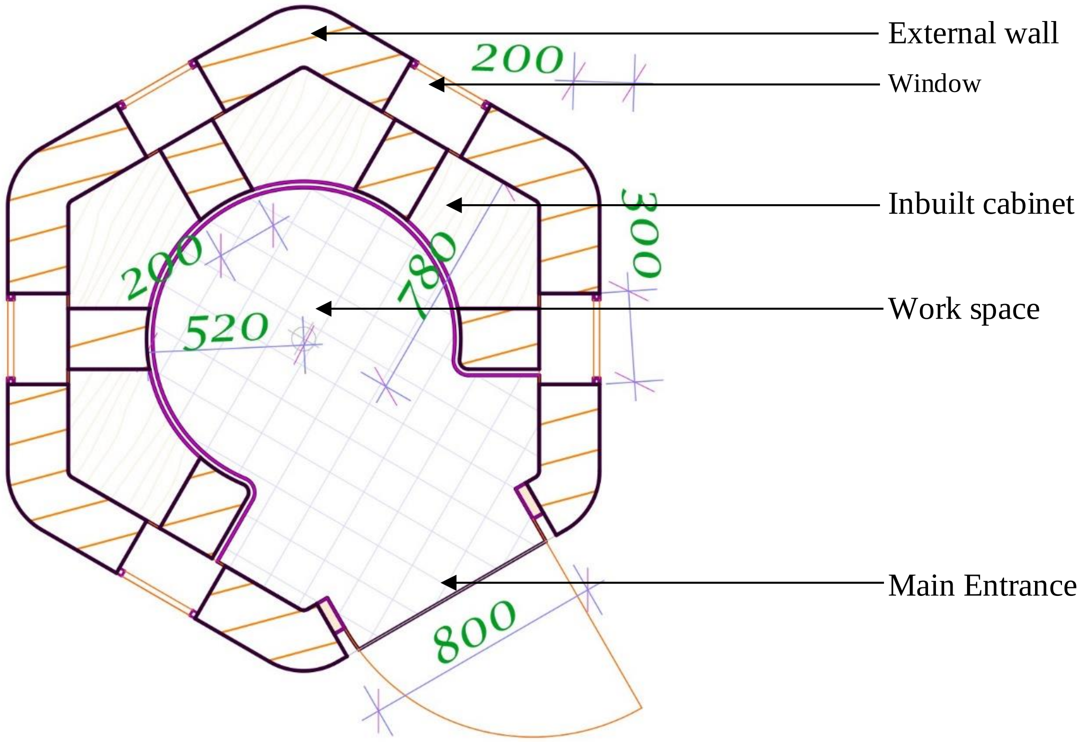


Figure 4.8.23 floor plan of the RBH
Illustration by researcher, 2020

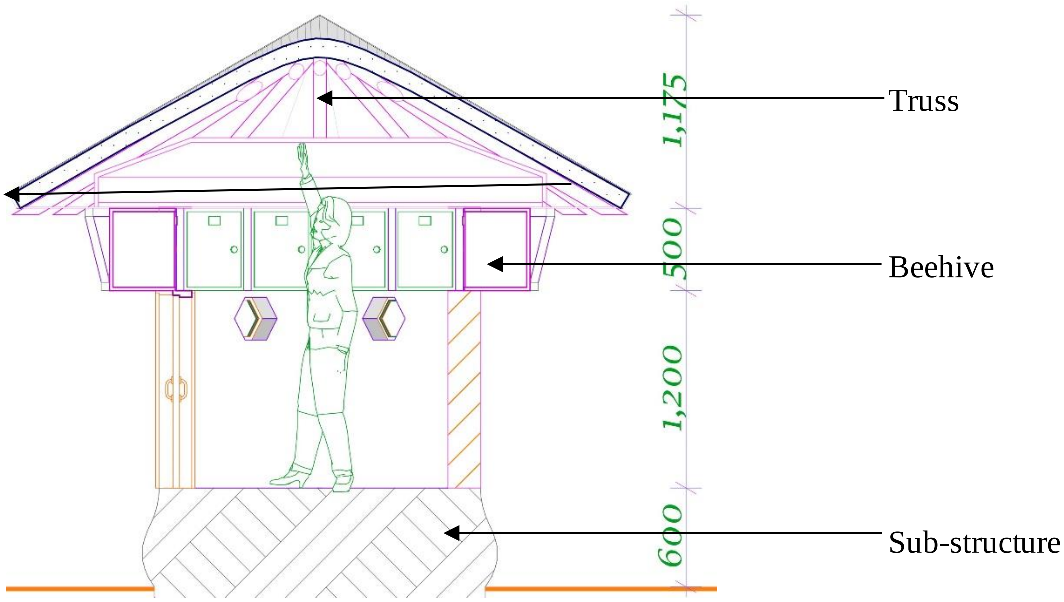


Figure 4.8.24 The functionality through a section of the RBH
Illustration by researcher, 2020

4.8.3.5 Challenges of the RBH

Whereas this RBH would be expected to produce more yields as compared to that in section 3.10.3, the researcher noted that the use of earth would compromise the safety of the RBH as it would easily yield to weather, and eventually the cantilevered beehives would collapse and the losses could become financially unbearable to the apiculturists.

It would also become complicated for some builders to accurately set up the hexagon shaped plan locally as most locally built structures are never more than circular or rectangular in shape hence this would frustrate the efforts of the builders. The shape also does not favor compact design hence encourages waste of materials and space.

The beehives in this design are also exposed and therefore vulnerable to thieves and vandals who can easily break them and steal the honey

4.8.4 Design 3

This design was aimed at simplifying the previous concepts so that the end product would be simple and easy for apiculturists to construct. The design also aimed at using stronger materials such as burnt clay bricks that would be more resistant to vandalism. It became necessary through the design to provide a cleaner environment that would support harvesting of honey by avoiding contamination associated with decaying materials such as grass and earth.

4.8.4.1 Source of inspiration

Since this design was aimed at simplifying the previous concepts so that the end product would be simple and easy for apiculturists to construct. One of the ways to achieve this was to extract the geometry factor in the hexagon and implement it on the rectangle as all of them were geometrical polygons yet the rectangle would be a simpler polygon to work with than the hexagon.

4.8.4.2 Conceptual design

The initial concept was to have a timber structure that would be raised from the ground as illustrated in the figure 4.8.26 below. The intent was to keep off potential predators such as rats and snakes form accessing the beehives within the structure. Out of the sketches a, b and c in figure 4.8.2.26, sketch b, was considered to offer the best layout within the RBH by allowing free circulation within the RBH.

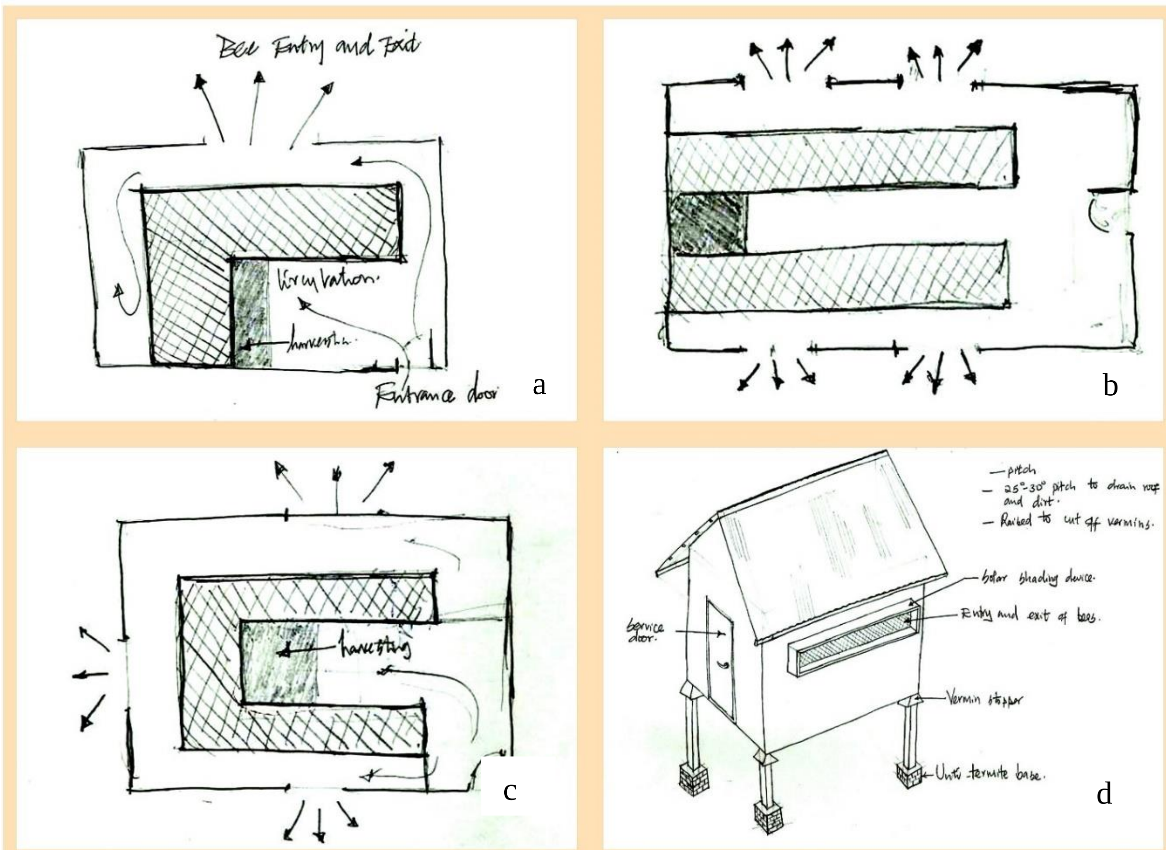


Figure 4.8.26(a, b, c) Different layouts of beehives in the RBH, (d) showing the external appearance of the RBH
Illustration by researcher, 2019

The researcher having observed the technicality of raising the structure above the ground, he explored the possibility of having an earthen structure that can be constructed on the ground and roofed. That felt a little bit simpler to be constructed by local apiculturists. That resulted to the development of the impressions in the figures 4.8.27 and 4.8.28

4.8.4.3 Visualization

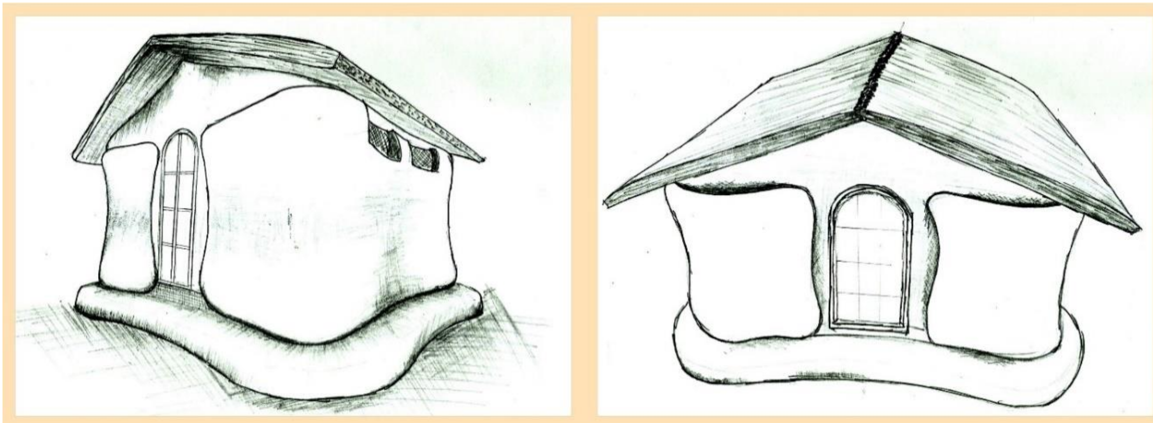


Figure 4.8.27 a pencil image of the earthen RBH with the curvilinear concept

Illustration by researcher, 2019

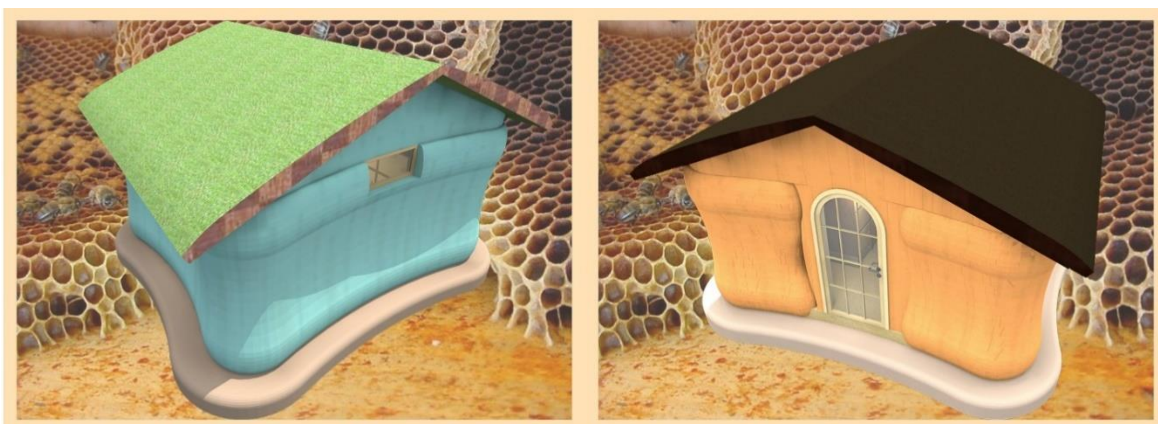


Figure 4.8.28 A CAD image of the external earthen RBH

Illustration by researcher, 2019

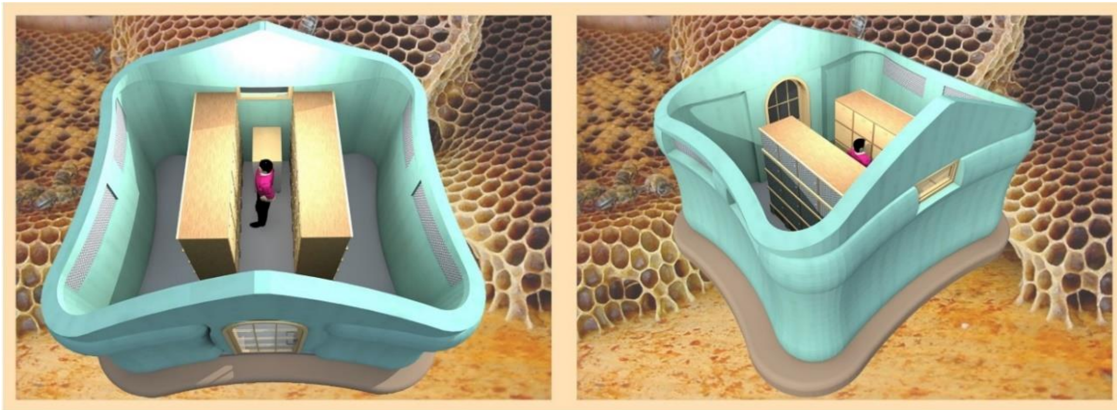


Figure 4.8.29 internal appearance of the RBH and on the background of the honeycomb so as to compare the fluidity of the RBH versus that of the honeycomb.
Illustration by researcher, 2019

The researcher felt that the curvilinear shape of this RBH would render it more complicated for apiculturists to have it constructed. He also felt that the use of earthen materials to construct the RBH would also render it less durable as the soil would be easily washed away by the rain. Those two reasons provoked the researcher to adopt a more linear shape that would be easy to construct and also to agitate the use of bricks as a way to encourage the longevity of the RBH.

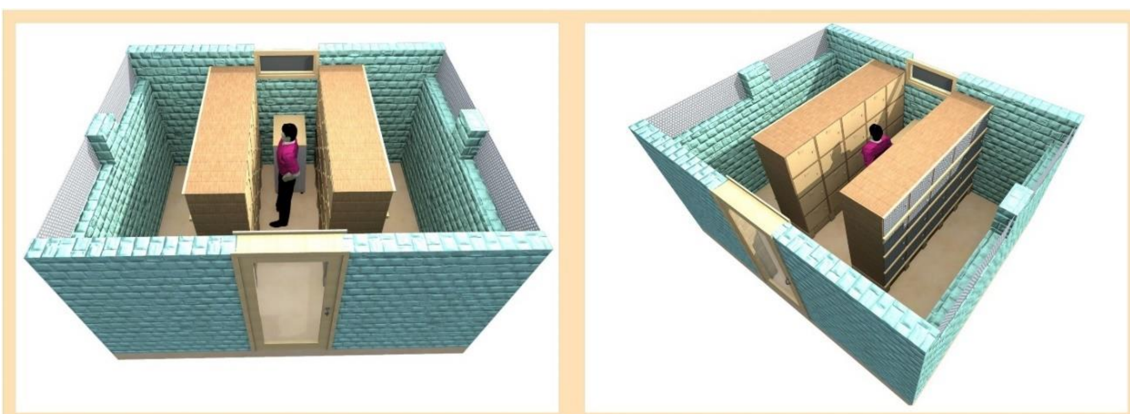


Figure 4.8.30 Transformation of the RBH from a curvilinear form to a linear form with the materials changed from earth to burnt clay bricks.
Illustration by researcher, 2019

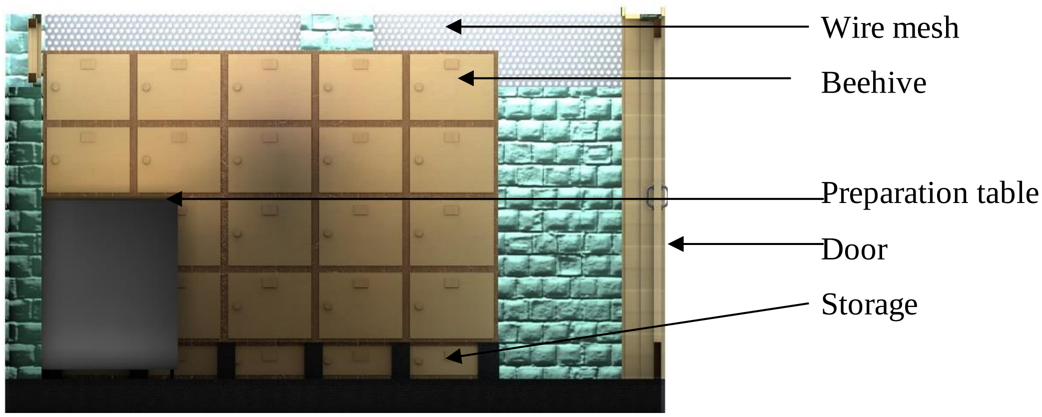


Figure 4.8.32 Section through the RBH capturing the stacks of beehives.

Illustration by researcher, 2019

Figure 4.8.33 A prototype of the RBH.

Photo by researcher, 2019

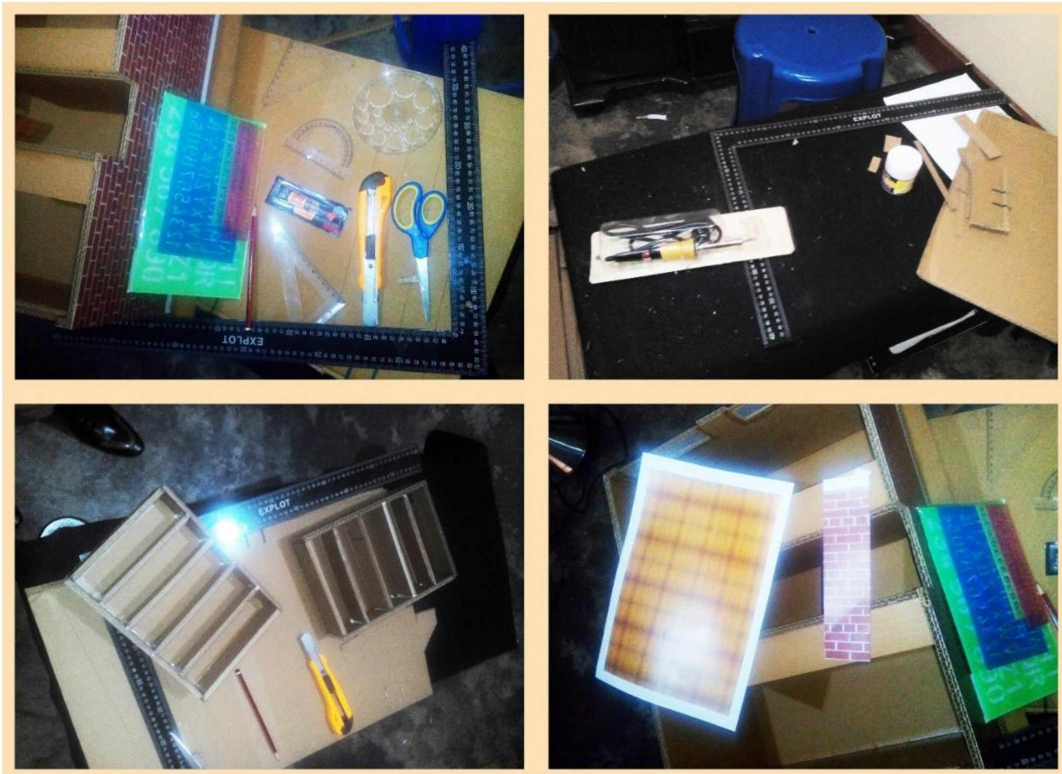


Figure 4.8.34 Different tools and materials used to construct the RBH.

Photo by researcher, 2020

4.8.4.4 Working drawings

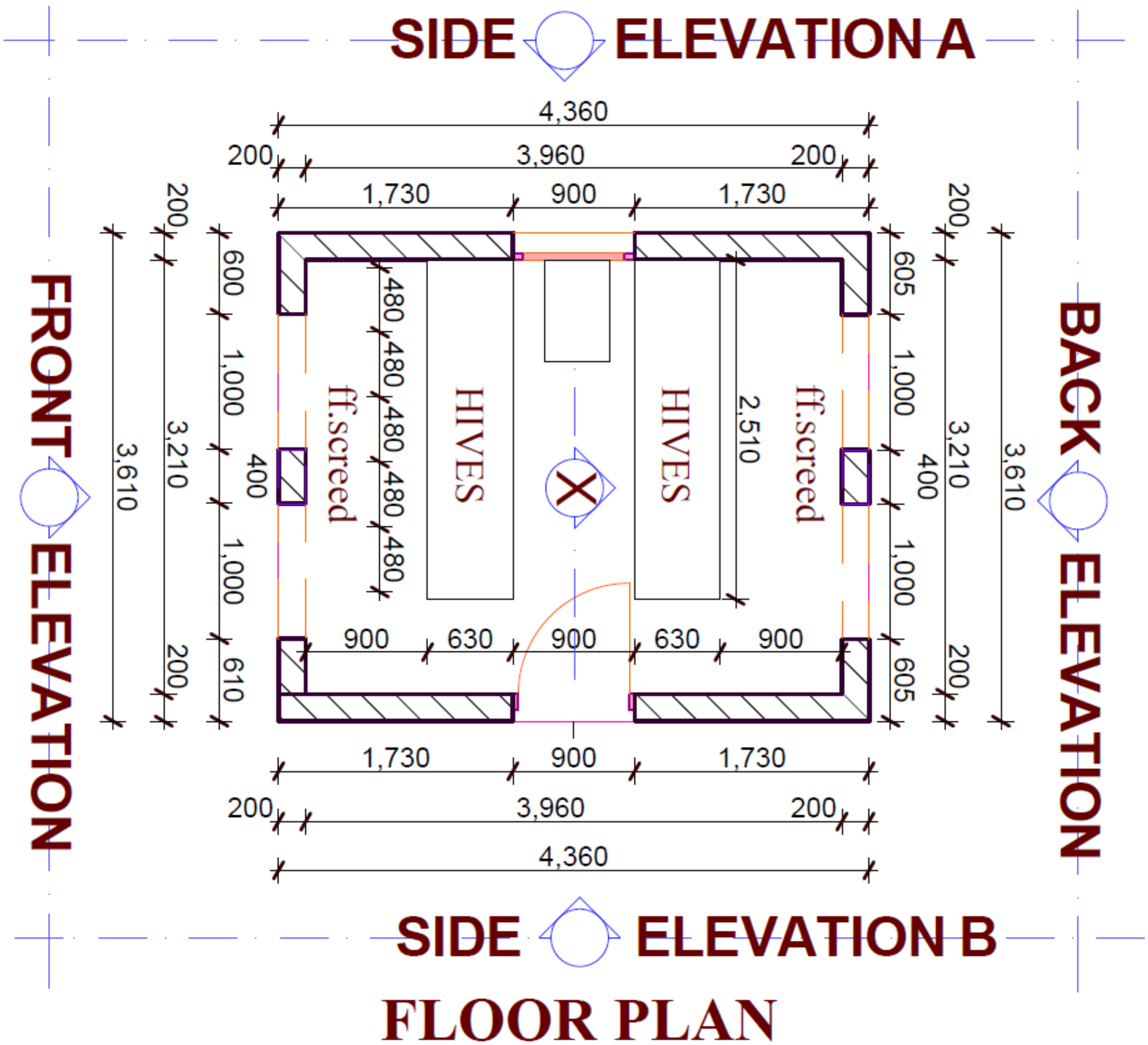


Figure 4.8.35 Plan of the RBH

Illustration by researcher, 2019

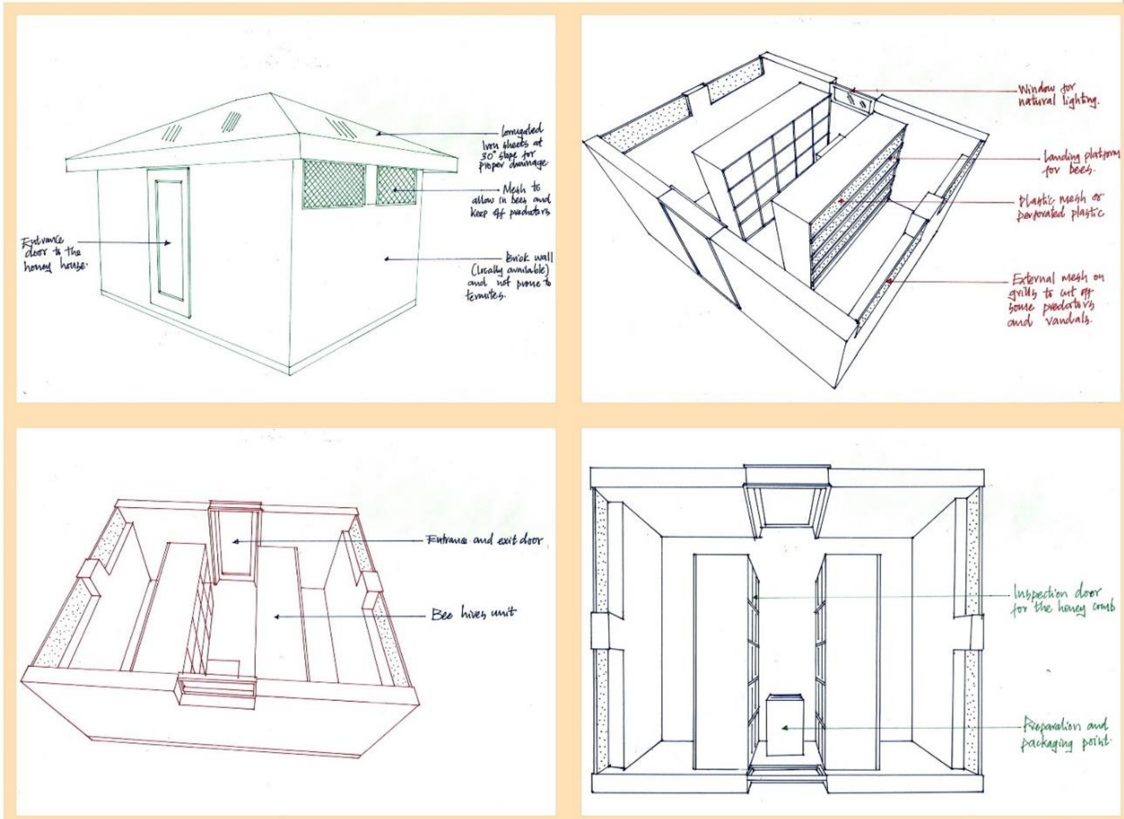


Figure 4.8.36 Technical drawings of the different views of the RBH
Illustration by researcher, 2020

4.8.4.5 Challenges of the RBH

Despite the fact that this particular RBH was considered by the researcher as simple to construct, the researcher observed that it was characterized by wastage of space as circulation of the apiculturist accounted for two thirds of the total floor area. Besides that, it only had the capacity to host thirty beehives which the researcher considered not worthy enough for the space.

4.8.5 Design 4 (The Ultimate Design)

4.8.5.1 Source of Inspiration

The design was inspired by two sources of inspiration which included the honeycomb as a major source of inspiration and mushroom which was a minor source of inspiration.

The honeycomb was deemed fit for being a major source of inspiration because the researcher realized that majority of laypeople who knew less about apiculture yet could be potential apiculturists quickly related with the honeycomb when one engaged in the discussion about apiculture.

That was attributed to its significance in the beehive as it was the primary store where the bees deposited the pollen grain which later was translated to honey. The honeycomb also exhibited great sense of beauty by virtue of its intricate designs of precise geometric polygons. Such significant factors provoked the researcher to commence developing studies about the honeycomb so that they could inform and influence the RBH design.

Poppick (2013) tells us that some people believed that the bees had the ability to precisely construct angles therefore accurately constructed the hexagonal cells. She goes ahead to note how much the scientist globally have also marveled at the angular precision of the honeycomb and that engineers showed that each cell begins in circular shape which is attributed to the shape of the bee's body. When the bees grow up in the cells, they cause the wax to become molten and flow like lava which causes the walls to naturally morph and acquire the shape of the hexagon though she noted that the team did not understand how the bees heated the cells to cause the walls to naturally fall and acquire the shape of hexagon.

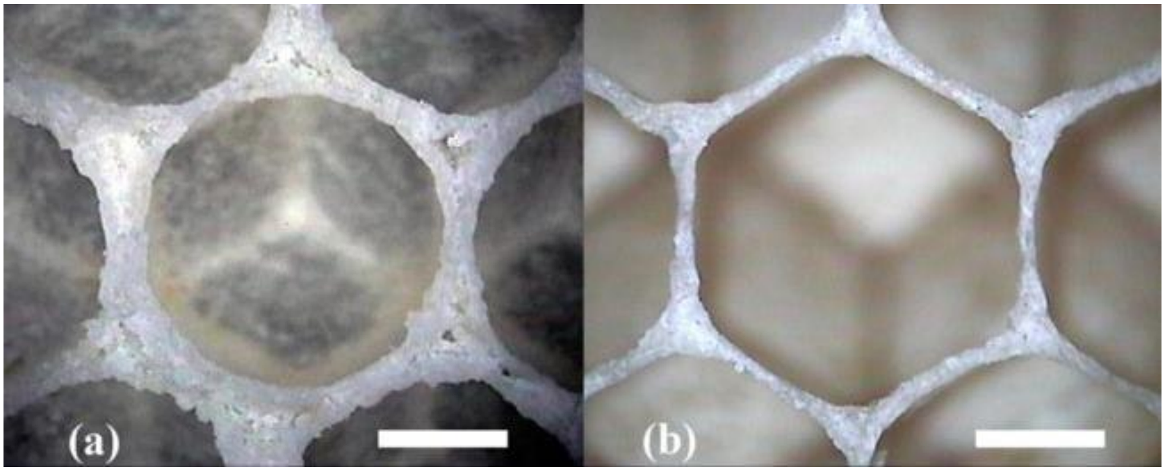


Figure 4.8.37 How the cells morphs from circular shape (a) to hexagon shape (b)
Author: B.L. Karihaloo, K. Zhang and J. Wang
Year: 2013

Out of the honeycomb study the researcher was inspired by the dynamic and transition of the geometric shapes from something that seemingly looked circular to eventually something that looks like a precise hexagon hence resolved to not only be constricted to a particular geometric shape, but also explore the dynamism other geometric shapes such as squares and rectangles as that defined the essence and the character of the cell in the honeycomb.

Having keenly observed honey, the researcher felt that the honey had an essence of organic flow and that best depicted its behavior of flow. That organic flow of honey was best demonstrated by the curvilinear nature and fluidity of the mushroom. The mushroom was also coincidentally found to be an easy to relate to source of inspiration since it has a very rich history globally besides being a local delicacy in some of the homes in Sheema District.

Ellen Lloyd (2020, p.3) noted that In Roman civilization, the mushroom, while appreciated for culinary qualities, was a symbol of death fungus. The term fungus meant "bringer of death" (from the Latin funus = death and needle = port, lead). However, the ancient Egyptians, believed there was a special connection between mushrooms and gods. According to ancient Egyptians, wild mushrooms were the “sons of the gods”, sent to Earth by lightning. Only the Pharaohs were therefore allowed to eat them. Ancient Egyptian hieroglyphs reveal that Pharaohs thought mushrooms were sacred herbs that you could consume to become immortal. The evidence that revealed the connection between the ancient Egyptians and the mushrooms are revealed in figure 4.8.38.

Figure 4.8.38 Persephone and her mother Demeter admiring each other's mushroom (Left) and mushroom stones found with Metates which were presumably used for grinding the sacraments.

Source: www.mushroomstone.com

Year 2020

Whereas elsewhere the mushroom might have been perceived as a symbol of deity or a symbol of death, to the Locals in Sheena District, the mushroom was only appreciated as a source of delicacy.

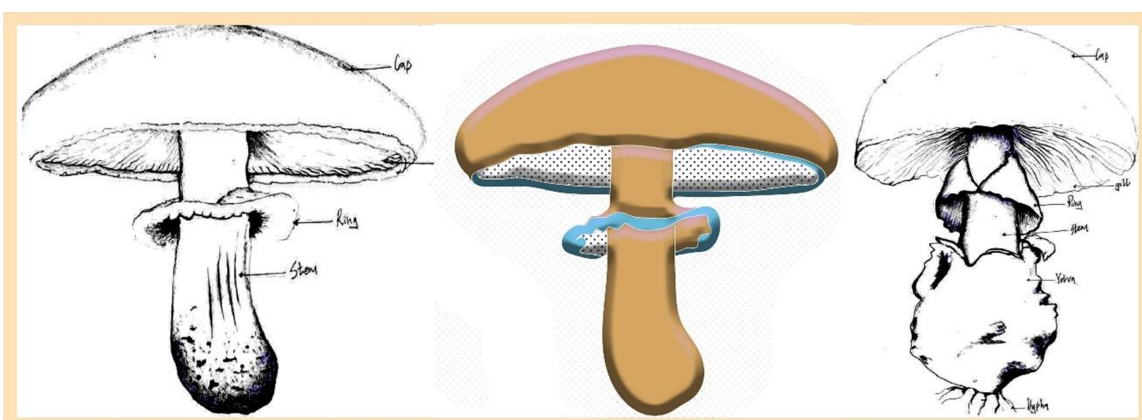


Figure 4.8.39 Various mushrooms hand drawn and enhanced with photoshop (CAD program)

Illustration by researcher, 2020

Figure 4.8.39 shows the different sections of the mushroom. The researcher picked several major sections of them to inspire the RBH design. Those sections included the stem, the ring and the cap. The stem was considered to be very essential in anchoring the mushroom into the ground hence created stability. The RBH will therefore consist of a substructure which will stem out of the ground to provide stability to the RBH.

The mushroom also consisted ring which was in between the stem and the cap. The RBH will consist of the beehives as the ring in every harvesting chamber, and these rings of beehives will be between the foundation and the roof of the RBH. Finally, the mushroom consisted of the cap which provided a protective shelter to the mushroom against the weather, and so the RBH will have a roof structure that will act as the cap to provide shelter from weather to the RBH. It was also exciting to explore the texture of the mushroom so the researcher experimented with Maya CAD program to achieve the texture of the mushroom as shown in the collection of the pictures in figure 4.8.40.

Figure 4.8.40 The surface texture of the mushroom as designed by Maya (CAD program)
Illustration by researcher, 2020

The top view of the mushroom shows a focal space that is central and the patches of the texture radiate about that focal space. The researcher therefore thought that the extraction space which the apiculturists had desired shall be central in the RBH, then the rest of the spaces such as the harvesting chambers and the water tank would act as the patches radiating from the extraction space. A further research revealed that there were many more shapes and forms of mushrooms which were classified by either by gill attachment or cap morphology.

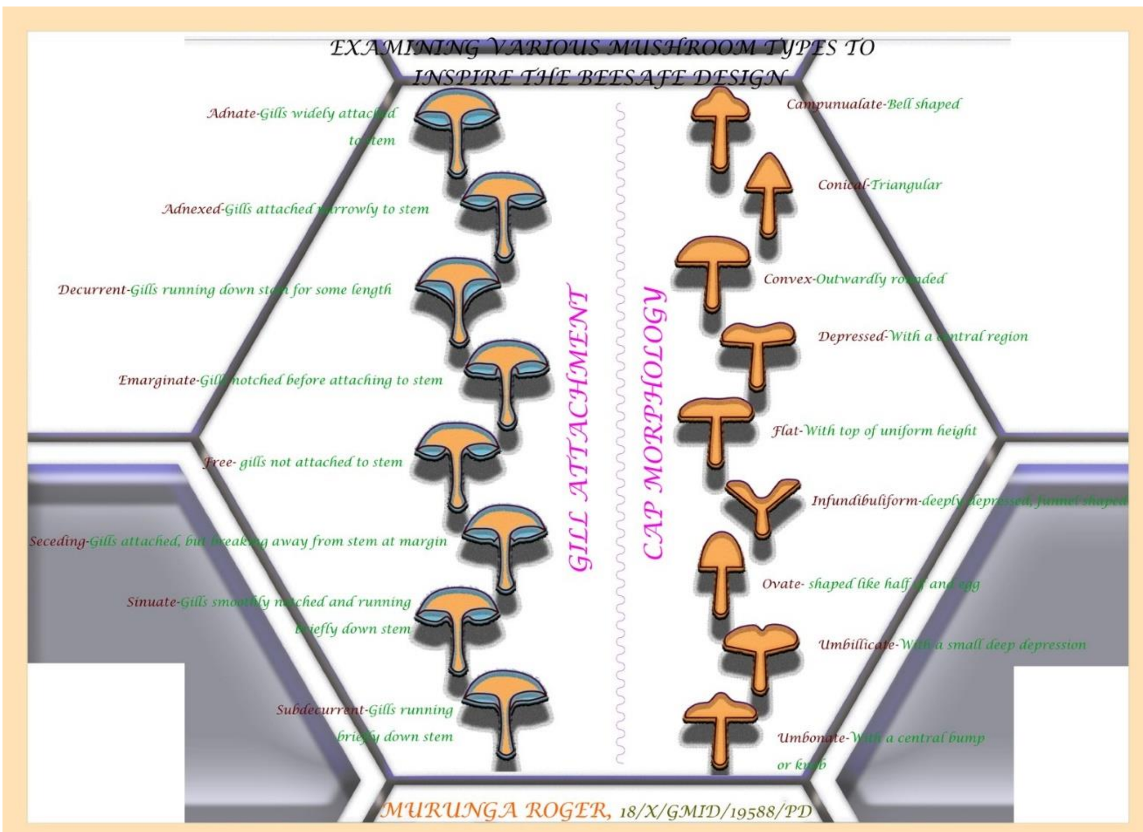


Figure 4.8.41 The different classifications of mushrooms
Illustration by researcher, 2020

Out of the research above the researcher thought it wise to select one of the mushroom cap shapes to inspire the RBH roof design. The shape of choice was that of the infundibuliform mushroom. That shape was selected because it would allow the roof to collect water at the center of the RBH hence minimizing the cost of having a gutter all around the RBH to collect storm water.

4.8.6 Conceptual design

With the concept of spaces radiating from a focal space as extracted from the mushroom, the researcher developed a bubble diagram to capture that inspiration by having the extraction space at the center while having the harvesting chambers and the water tank radiate from it.

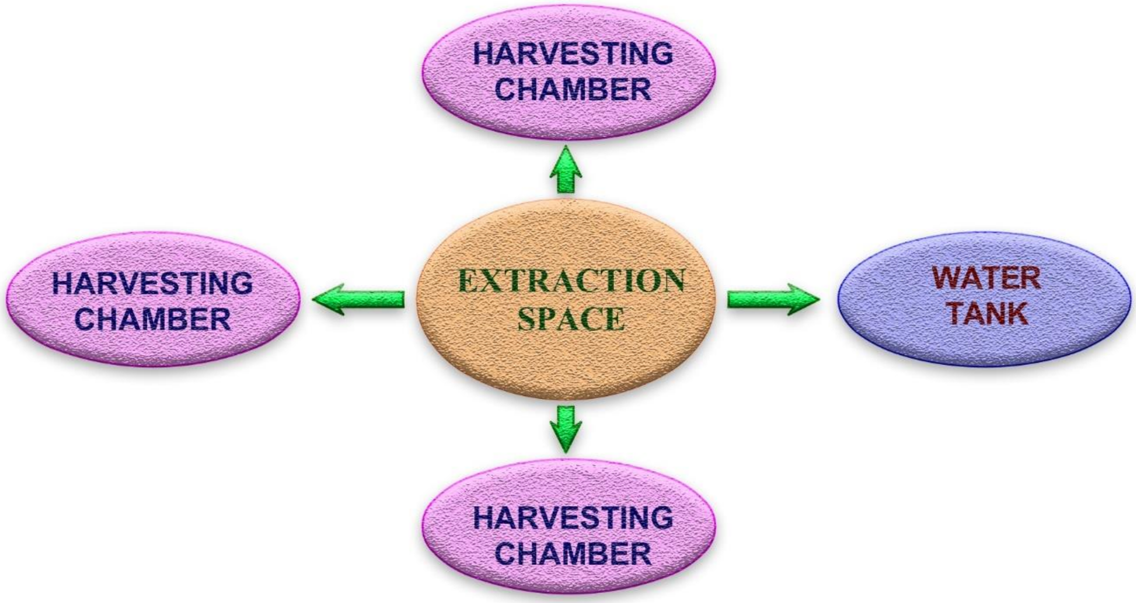


Figure 4.8.42 A bubble diagram of the major spaces of the RBH
Illustration by researcher,2020

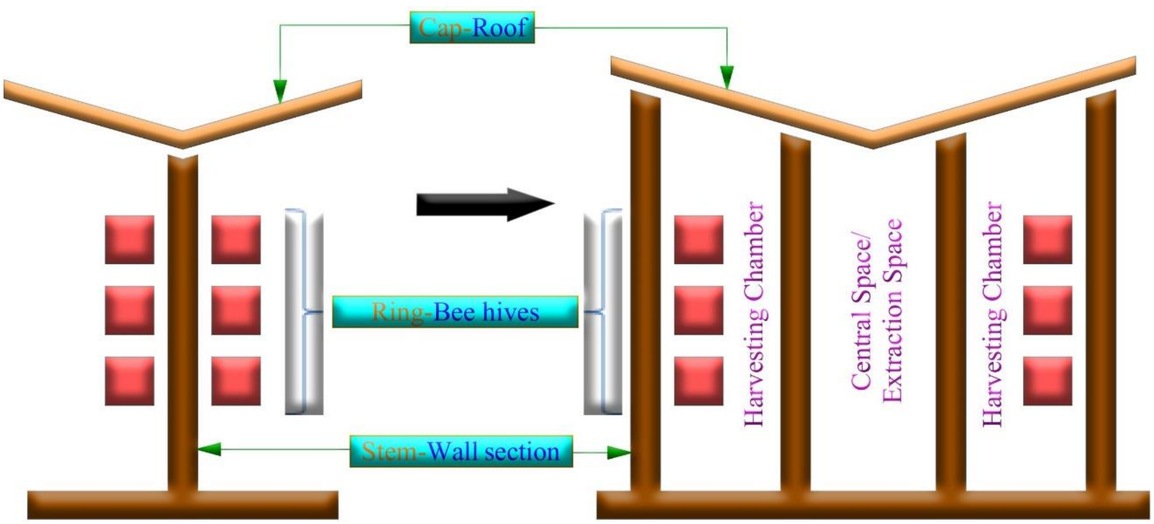


Figure 4.8.43 Concept development of the RBH from the infundibuliform mushroom as a source of inspiration.
Illustration by researcher,2020

4.2.4 Scheme Design

When respondent R1 was consulted about the need to have a RBH that would serve multiple functions as opposed to just keeping bees, he responded by saying the following;

> That would save us a lot in terms of costs, time and resources involved in, in terms of providing security for the honey as we wait for it to filter. But if we could do that in one place, that would be great for us.

respondent R1 was also consulted for his opinion in regard to the most appropriate materials that would consist a successful RBH and he had the following to note;

> A safe beehive, one, you must have to use wood somehow and protect the bees themselves and the honey because for them they make their own food and not for you the consumer, for them they make their own food and along the way, you come and take it! So, it is important that you make hives that would protect the bees and the honey. So, the materials to use are…, wood has to be involved and you have to cover it up so that you protect it against the weather and also you have to make it user friendly so that it is very easy for someone to get in and use it.

When the respondent gave the above feedback, the researcher noticed that that respondent was constricted to wood and only wood probably because that was what was used in that farm for apiculture. The researcher therefore gave Respondent R1 an example of the Bunka beehive from South Africa which was made of concrete with an effort to minimize theft and vandalism. The respondent replied that he was not sure about the cost implication of concrete but he mentioned that it would be a great idea to use materials that are more permanent so as to protect the bees. He continued by acknowledging that sand and cement were materials that were readily available in that area and would be welcome for use in the design of the RBH.

The researcher also noted that respondent R1 despite having sixty hives, he had the future plan of expansion to accommodate two hundred and fifty beehives. That implied that the intervention to the challenge of quantity of honey should aim at having fairly good number of beehives in the RBH to aid the ambition of such an enthusiastic apiculturist. The researcher therefore was obliged to design RBH that would consist of four major sections that included the extraction space, the harvesting chambers, and the water storage space.

The extraction space which is 2.4meter wide by 3.5meter long acts as the central circulation space for the RBH because it connects the three harvesting chambers in the RBH. It has an extraction table of 0.8meter wide by 2meter long because apiculturists needed a set apart space for extracting the honey from the honeycombs. The extraction table will also provide storage for keeping cleaning tools and harvesting equipment. The table will therefore be provided with shelving and drawers for storage.

Since apiculturists will have many Langstroth frames from which to harvest honey, a space will be provided besides the extraction table for stacking crates of the Langstroth frames loaded with honey. The crates will be used to carry the frames with honey from the respective harvesting chambers and placed annex to the extraction table for easy access to them. The crates will be designed in a manner so as to be mounted over each other to minimize space wastage in the extraction space.

The figure 4.8.44 shows the scheme layout of the RBH and the illustration of how the different parts relates to each other.

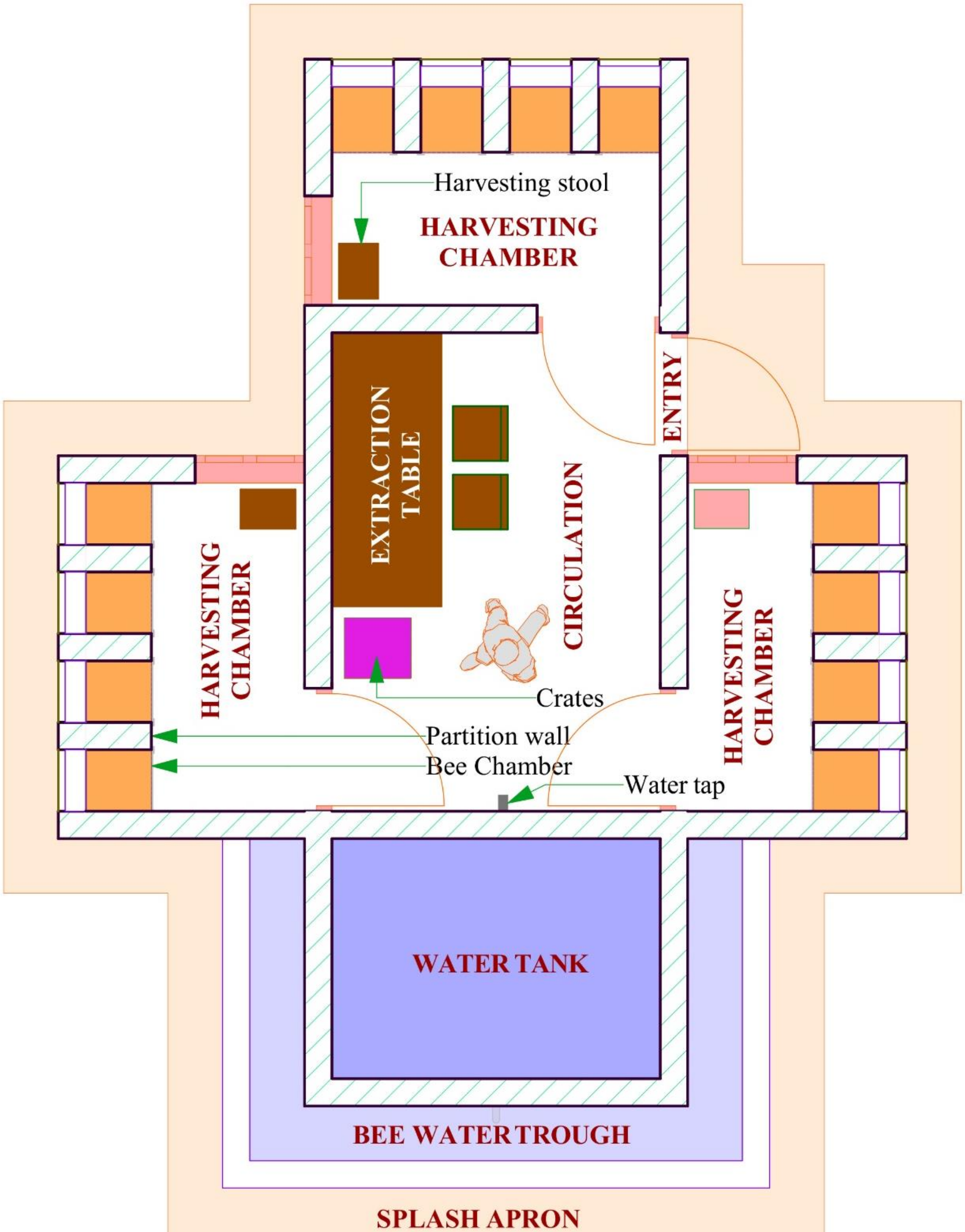


Figure 4.8.44 Layout of the RBH
Illustration by researcher, 2020

The harvesting chamber is 0.9meters wide and 2.4meters long is the space where the apiculturist directly interacts with the bees. Within that space, it is possible to open the beehives, inspect the beehives, smoke the bees off the supers and harvest the honey by pulling out the frames with honey, then replace the frames after extraction of honey has been achieved. That solves the challenge apiculturists have of harvesting honey in the event that say it is raining. The harvesting chamber has a door which barres the bees from getting into the extraction chamber where they would turn out to be a menace to the extraction process of honey.

The harvesting chamber has a high-level window that gives provision for both natural lighting and ventilation of the space. That is necessary especially if inspection of the hives and harvesting of the honey is to be done during day time. The high-level window also acts as an exit for the bees that get into the harvesting chamber during the process of inspection and harvesting of honey in the chamber.

Each harvesting chamber has four columns of beehives. The columns are separated with a 200-millimeter brick wall which offers good insulation around the beehives hence keeping the bees from the drastic weather changes which affect the bees.

Each column of the beehives consists of three hives arranged vertically and each of them seats on a light weight reinforced concrete slab that runs through the entire level of the harvesting chamber.

Every hive consists of a brooder, two supers and a lid. The brooder has the entrance and exit for the bees on the external wall of the RBH. The frames in the brooder seats on the slab which acts as the base. On top of the brooder frames is a wooden frame covered with coffee mesh to prevent the queen bee from climbing to the super above. The wooden frame with coffee mesh is placed on wooden frames nailed onto the wall on both sides of the walls. That wooden frame becomes the platform upon which the frames for the super are placed for support. Above the first supper is another wooden frame suspended on both ends of the walls, and the second super frames are placed on that frame. The first and second super are encased between light weight concrete slabs while the third beehive has a lid on top of its second super.

The wooden frame was inspired by that of Langstroth beehive because Langstroth did recommendable research about the bee space and came up with a standard frame upon which the bees could comfortably and conveniently build the honeycombs. Where's the Langstroth frame is standard, the actual dimensions of the frame varied slightly from one Langstroth beehive to another. The researcher therefore found it necessary to adopt a standard frame with specific measurements for the purpose of coming up with a standard customized RBH.

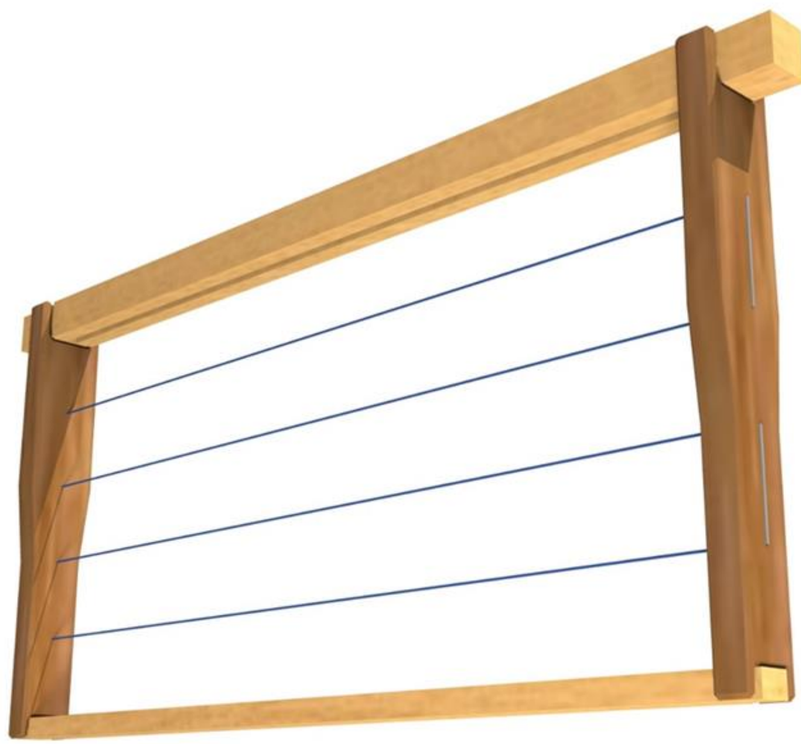


Figure 4.8.45 The Langstroth frame to be used in the RBH (Designed by ArchiCAD and rendered in Atlantis CAD programs
Illustration by researcher, 2020

The Langstroth frame consists of a wooden top bar, two wooden side bars and the bottom wooden bar. The top bar is made in a manner such that when the frames are placed abreast each other, they leave a space between them for bees to move from the brooder to the supper and also from one supper to the to the other above. It also has a 0.5milimeter groove below it where bee wax is smeared on to act as a foundation upon which bees should construct the honeycomb.

The two side bars have small holes drilled in them so that binding wire can be tightened trough them. The binding will offer support to the honeycomb so that the honeycomb will not break during the process of extraction of honey from the combs.

The bottom bar if basically for support and smaller than the top bar. It allows the also the bees to freely move from one supper to the next below. Both the brooder and the supers consist of 12 frames and each of them is laid abreast each other.

Figure 4.8.46 The Langstroth frame being constructed by a local carpenter under the supervision of the researcher to test the ability of the carpenter to capture it precisely
Photo by researcher, 2020

The researcher decided to do a simple test run so as to observe how easy of difficult it could be for the carpenters to make this Langstroth frame. One carpenter was given just the drawings while the second was given the drawing together with a sample of the frame. The one given just the drawings made remarkable mistakes on the thicknesses of the bars without noticing while the one given the drawings plus a sample was able to capture the frame precisely correct. That informed the researcher that whereas a drawing could be perfectly done, some carpenters may never have the ability to visualize well except that they find something visible to relate to.

Having found out from the research that during the dry seasons the ponds and rivers go dry, it became important to provide a water storage tank that could store storm water and have it used at such a moment of scarcity. That would keep the bees around and prevent the chances of swarming in the attempt to look for water sources. The researcher therefore provided a 7000-liter water tank on the assumption that if the bees for instance consumes about 30 liters each day, then the water tank would have the capacity to sustain the bees for about four months through the dry season and still have enough of it for cleaning the RBH. That becomes a reliable source of water during the dry season. The water tank will have an overflow outlet above to allow excess storm water to flow out of the tank during heavy downpour.

Around the water tank will be a shallow trough which will be fed by a horse from the tank itself. Short shrubs shall be recommended around the water trough to create a canopy around it to create a cooling effect hence keeping the water cool for consumption by the bees. The horse will be powered by a tap which will be located in the extraction space. That will be so to safeguard the water from being let free to flow by an ill-fated individual or anyone who might want to use the water for any other reason not related to the bees and the RBH.

The roof which is infundibuliform shaped has a gutter at the center which collects the storm water from the sheets into the water tank. That arrangement reduces the length of the gutter that would have been otherwise used if the roof was to be for instance gable and the gutter had to move all around the building.

4.2.5 Visualization

To address the challenge of theft and vandalism, the RBH will have a burglar proof entrance that is approached through gardens of flowers which provide an immediate source of pollen grain for the bees. The flower gardens will keep the bees closer as they will provide an immediate source of pollen grain. Figure 4.8.47 shows also the different entrances of the bees into their respective beehives. Those entrances will have a coffee mesh placed internally so as to keep away the rodents such as rats which are predators to the honey collected by the bees.

Figure 4.8.47 Front side of the RBH highlighting the entry and exit of apiculturist(s) as well as entry and exit of bees into and out of the beehives.

Illustration by researcher, 2020

Figure 4.8.48 Water trough around the water tank that will be used during dry seasons.
Illustration by researcher, 2020

Around the RBH will be a 400millimeter wide splash apron which will keep the foot of the RBH free from grass and shrubs that that would otherwise attract rodents and creeping plants.

Figure 4.8.49 A section-elevation through the RBH to capture the fittings.
Illustration by researcher, 2020

4.2.6 Working Drawings

Working drawings were developed to enable the apiculturists with the help of local builders build the RBH without much challenges.

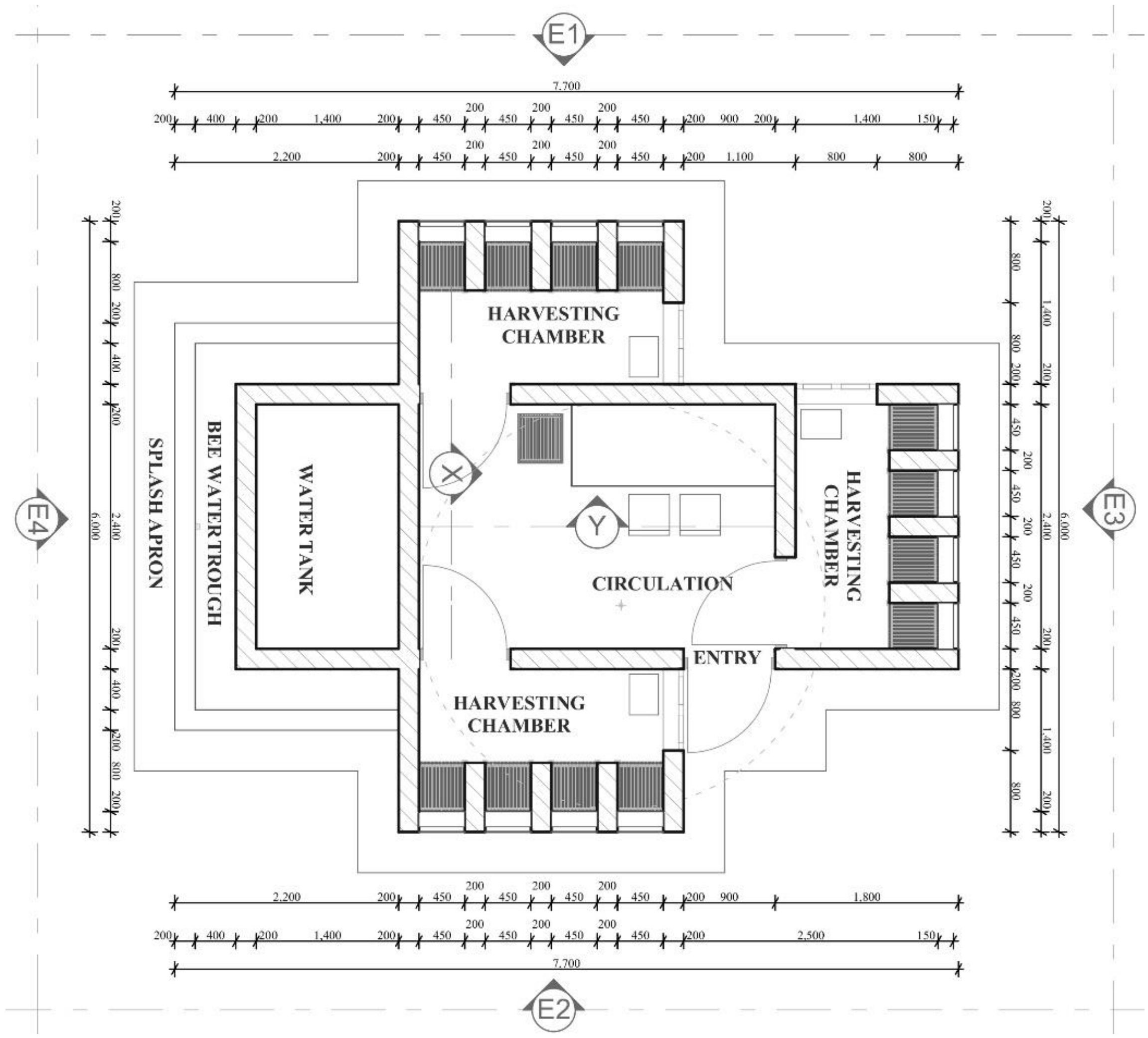


Figure 4.8.50 The different parts of the plan of the RBH

Illustration by researcher, 2020

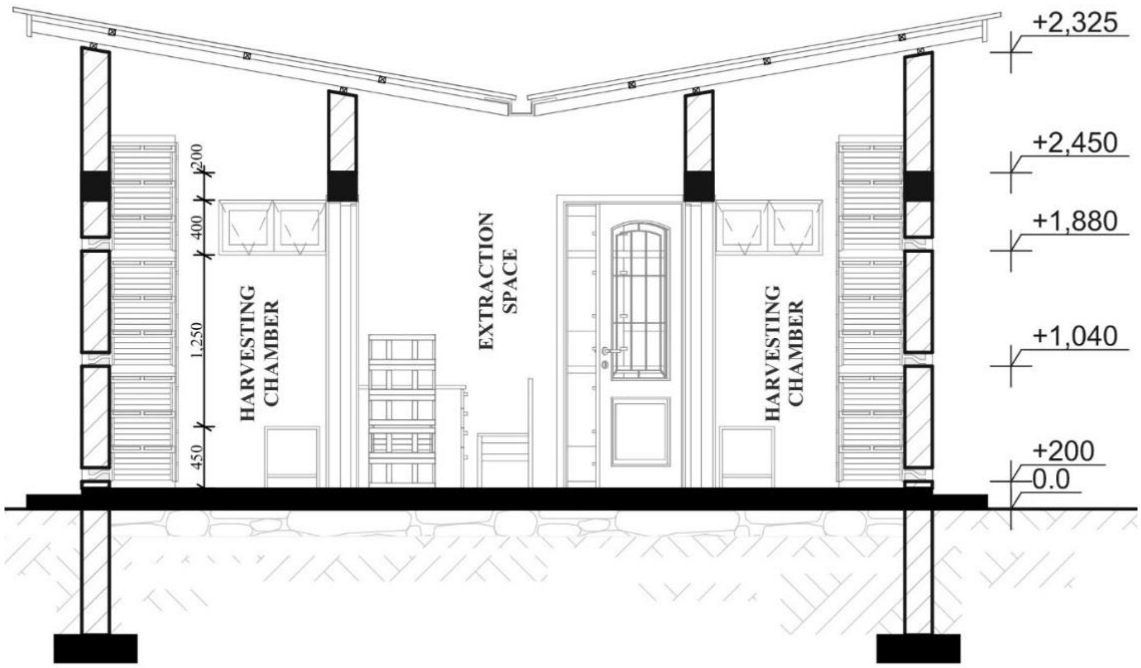


Figure 4.8.51 Cross-section X through the RBH captures the lintels.
Illustration by researcher, 2020

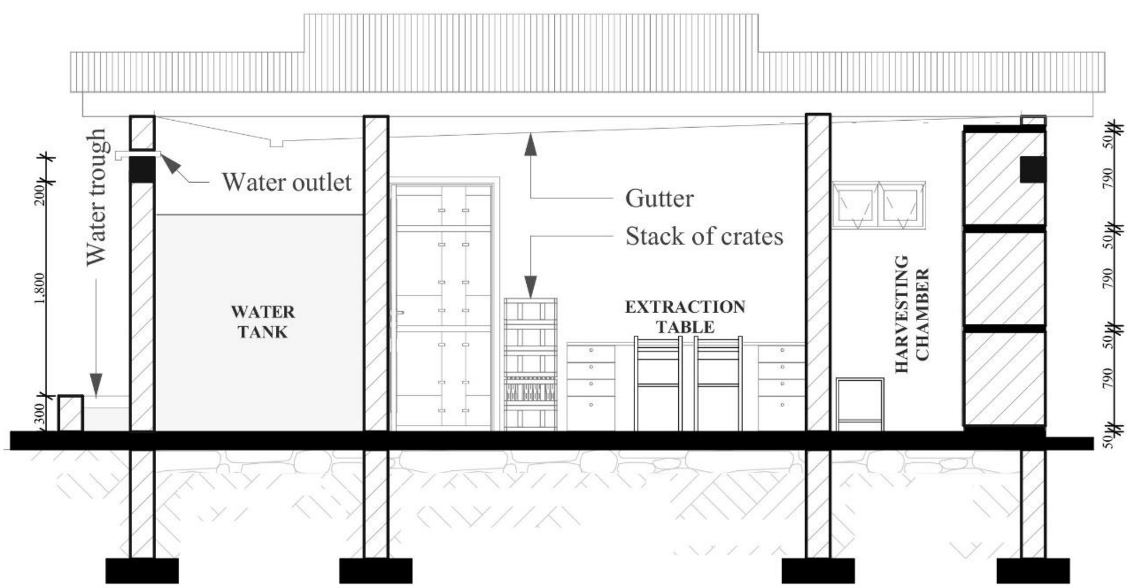


Figure 4.8.52 Longitudinal section Y through the RBH capturing the beehive slabs
Illustration by researcher, 2020

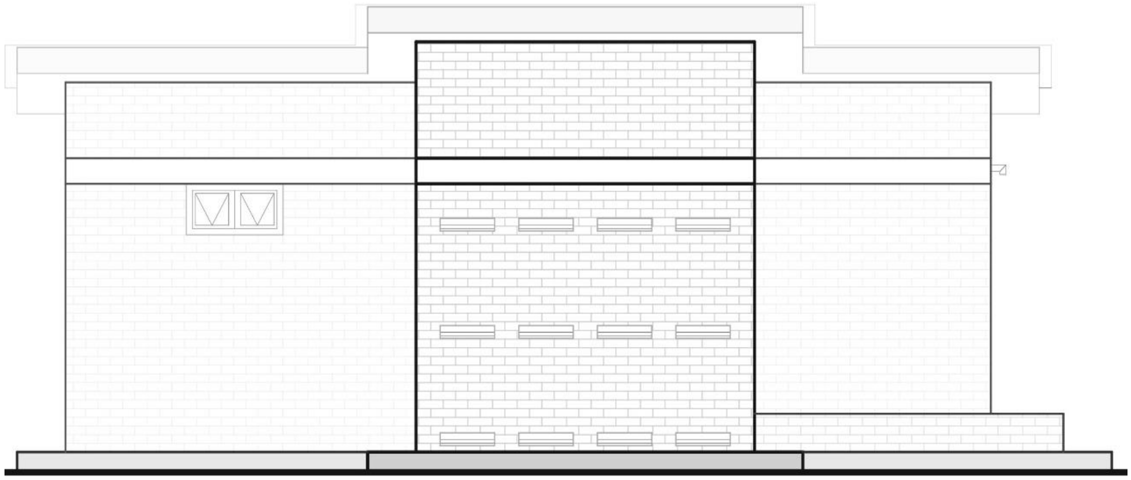


Figure 4.8.53 *Elevation 1 of the RBH capturing the bee entrance.*

Illustration by researcher, 2020

Figure 4.8.54 Elevation 2 of the RBH capturing the entrance door.

Illustration by researcher, 2020

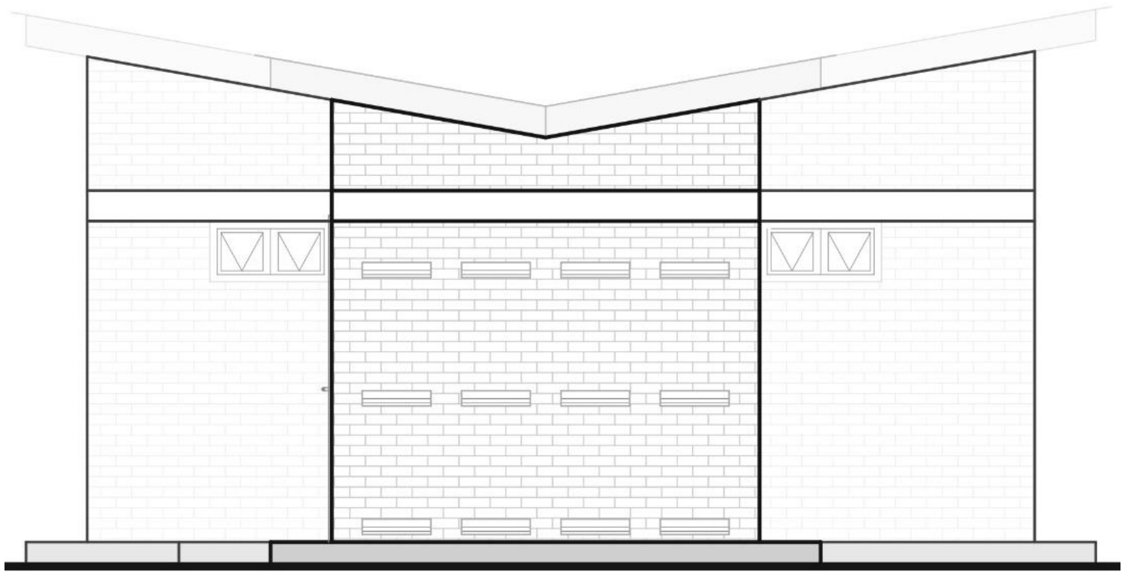


Figure 4.8.55 Elevation 3 of the RBH capturing the windows of the harvesting chambers.

Illustration by researcher, 2020

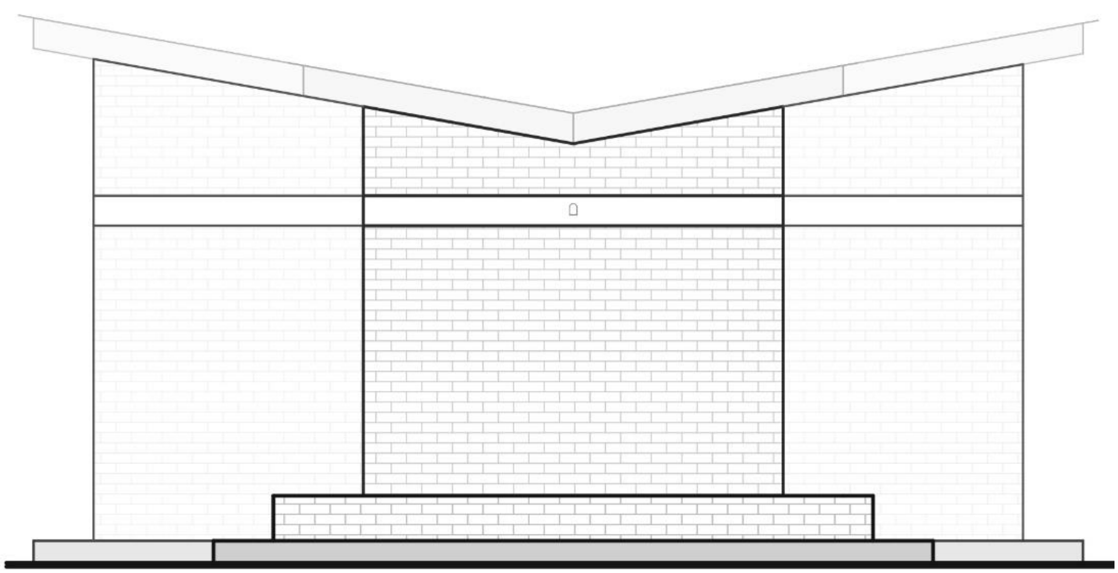
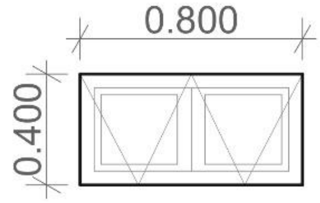
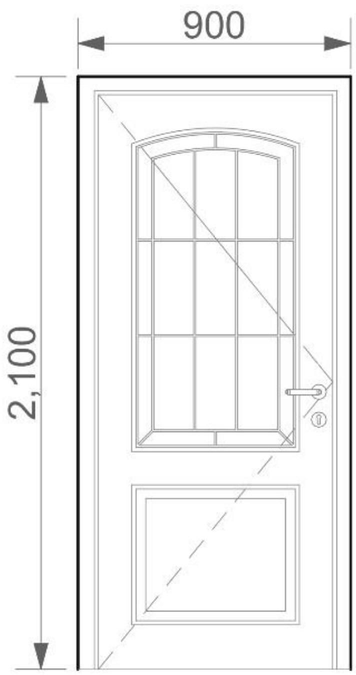


Figure 4.8.56 Elevation 4 of the RBH capturing the water trough.

Illustration by researcher, 2020

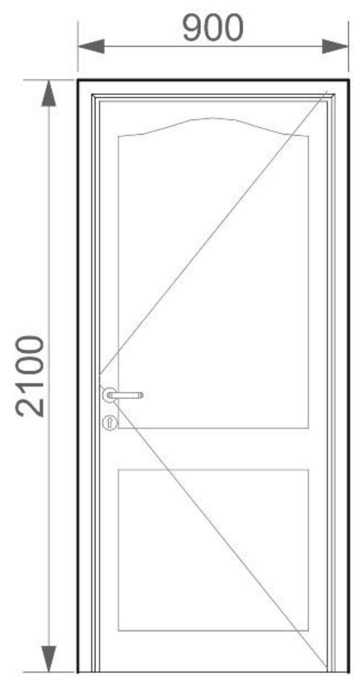


Steel casement window (3)



Steel Casement door (3)

External



Solid Core flush door (3)

Internal

Figure 4.8.57 The door and window Schedules of the RBH.

Illustration by researcher, 2020

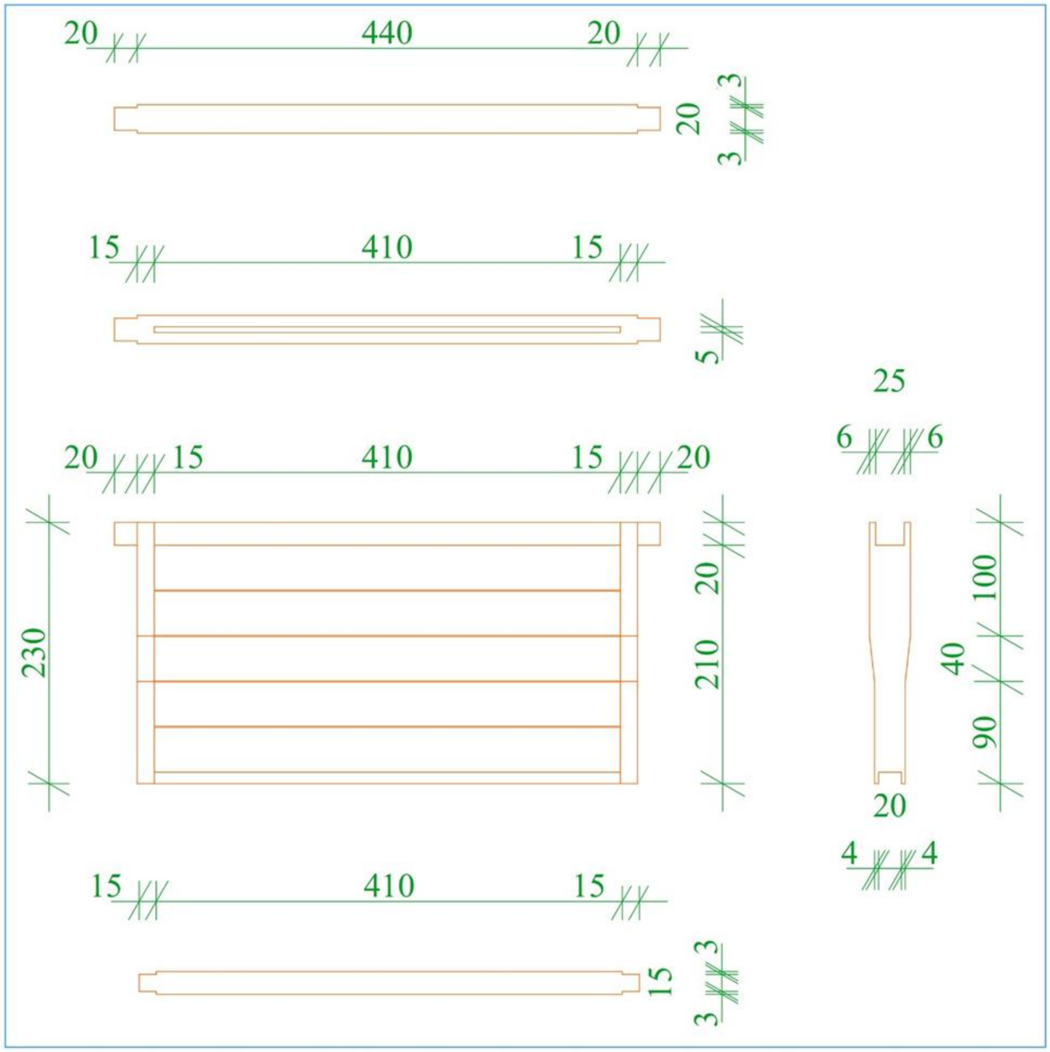


Figure 4.8.58 Detailed drawings of the frames used in the RBH

Illustration by researcher, 2020

4.2.7 Details

Three dimensional impressions were generated by way of CAD to aid the apiculturists visualize how the RBH components come together to form it as a whole.

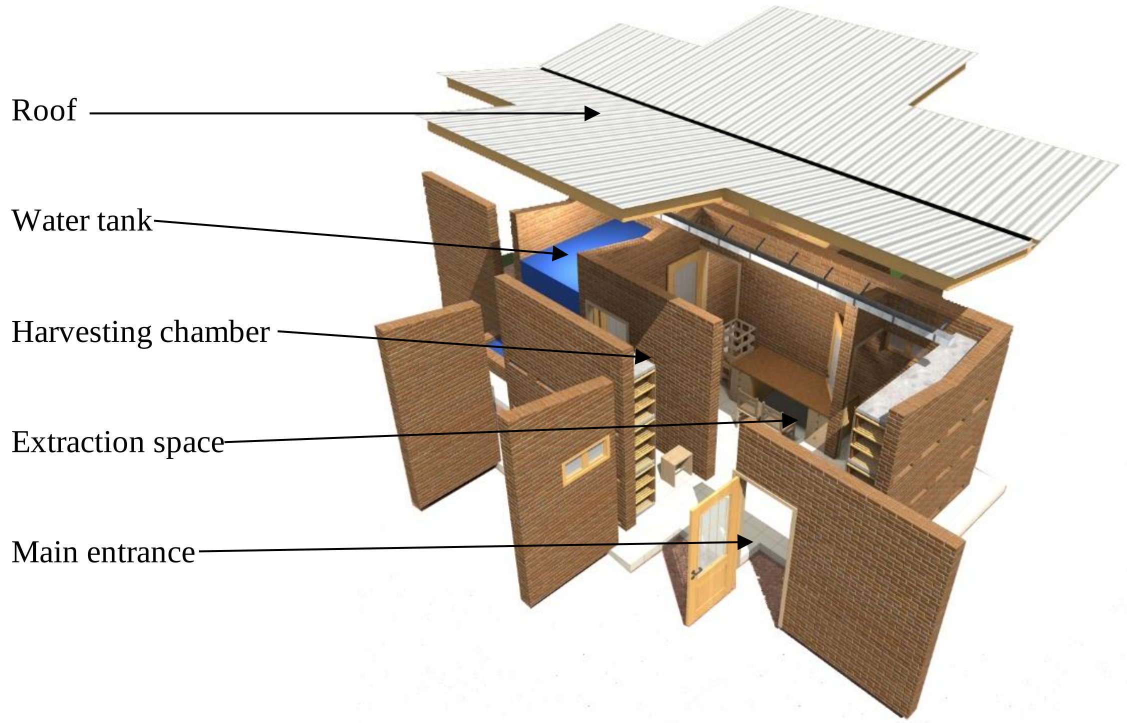


Figure 4.8.59 How the different components come together to form the RBH

Illustration by researcher, 2020

The harvesting chamber was also highlighted because it is the space that will essentially contain the inbuilt hives so the researcher decided to also demonstrate by use of CAD how the hives will connect into the wall chambers of the RBH.

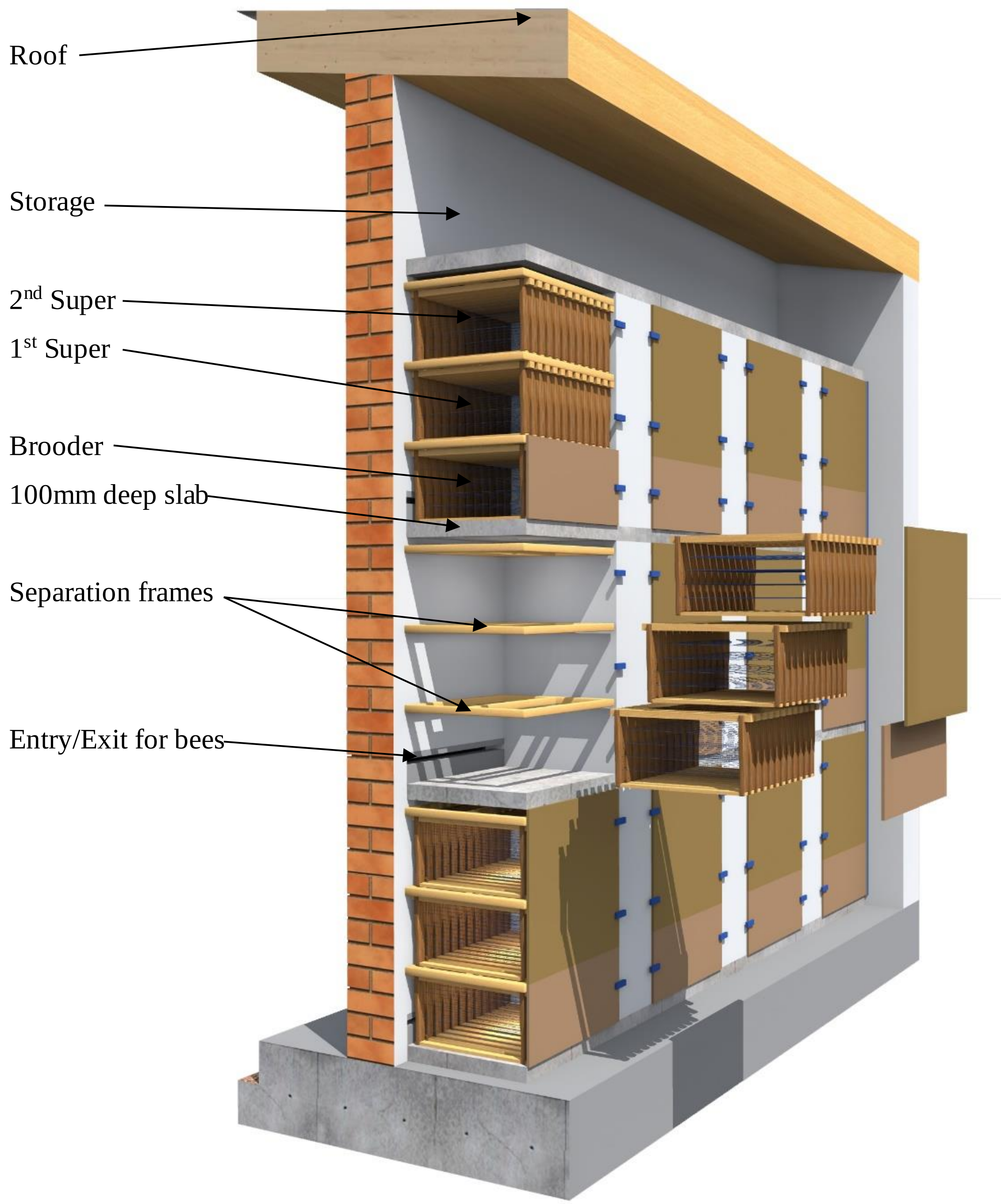


Figure 4.8.61 Section through the inbuilt hives of the RBH

Illustration by researcher, 2020

Every brooder and super will consist of twelve wooden frames. Since the frames will be many, it may become cumbersome to carry them independently especially during harvesting of honey. The researcher therefore decided to design a crate that has the ability to carry the twelve frames at the same time so as to ease movement within the RBH during harvesting of honey.

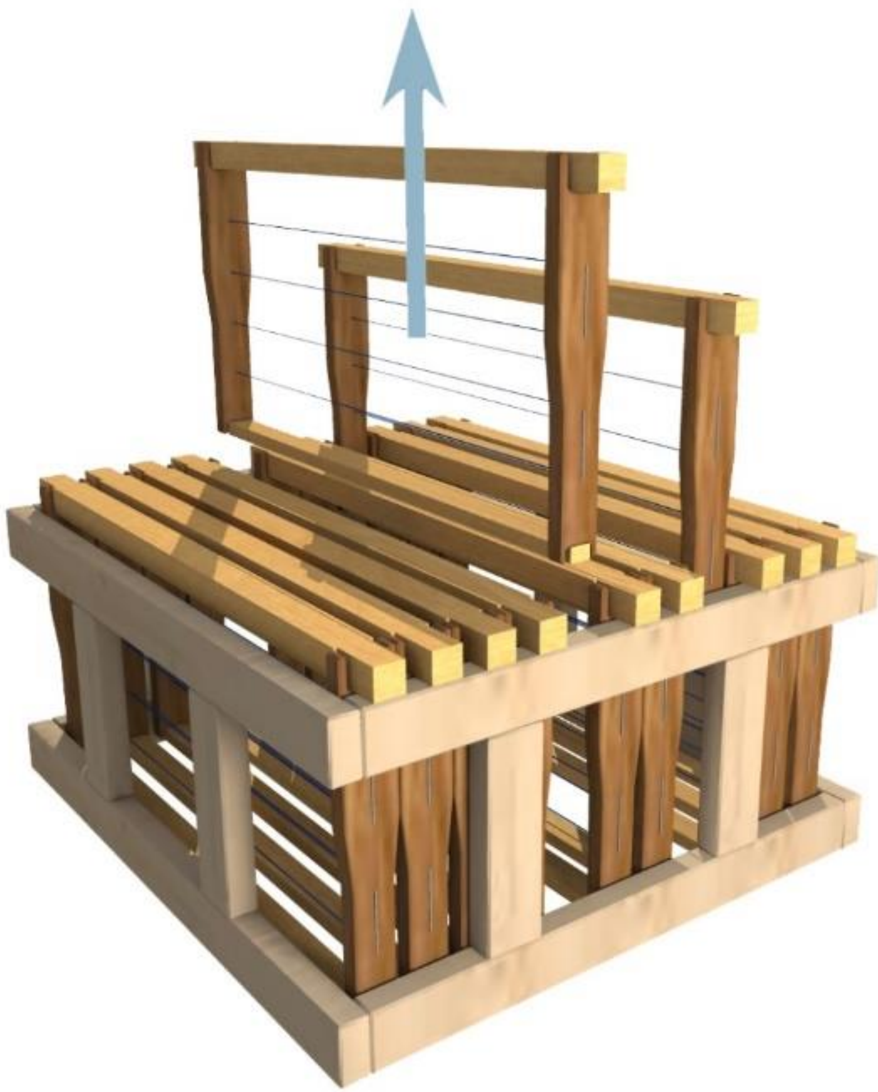


Figure 4.8.62 The crate laden with the 12 frames to be installed in the RBH
Illustration by researcher, 2020

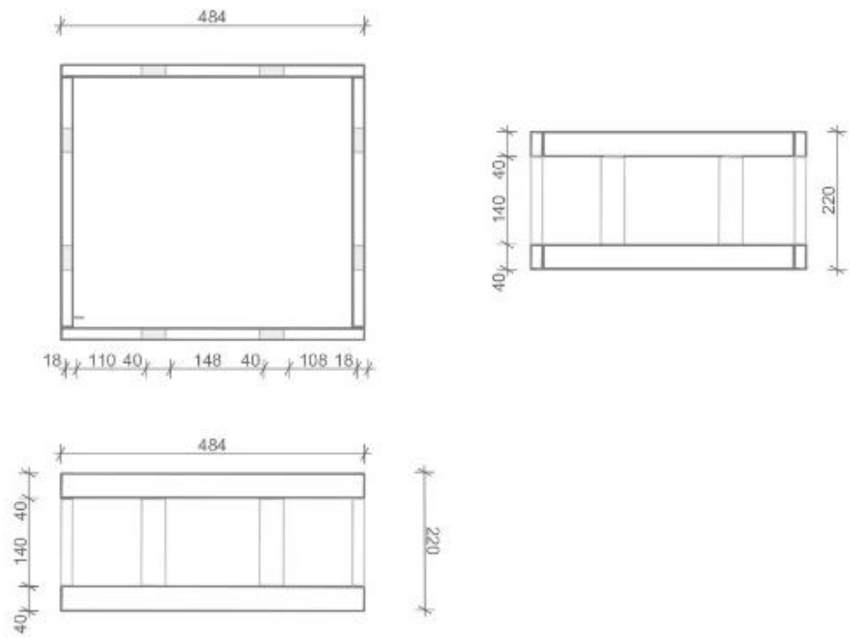


Figure 4.8.63 Showing the dimensions of the orthogonal projection of the crate

Illustration by researcher, 2020

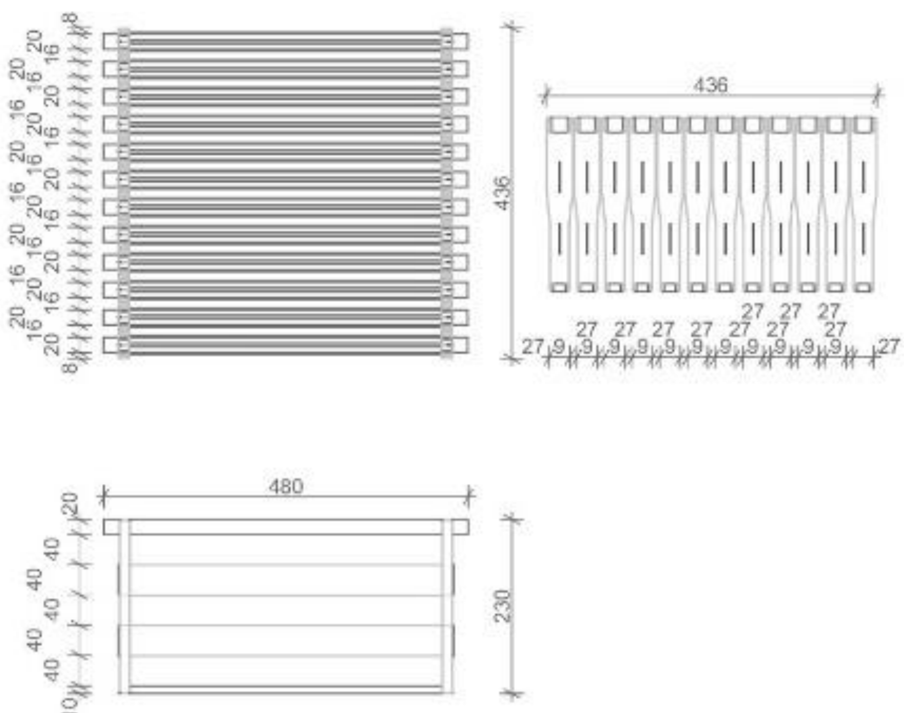


Figure 4.8.64 The dimensions of the orthogonal projection of the frames

Illustration by researcher, 2020

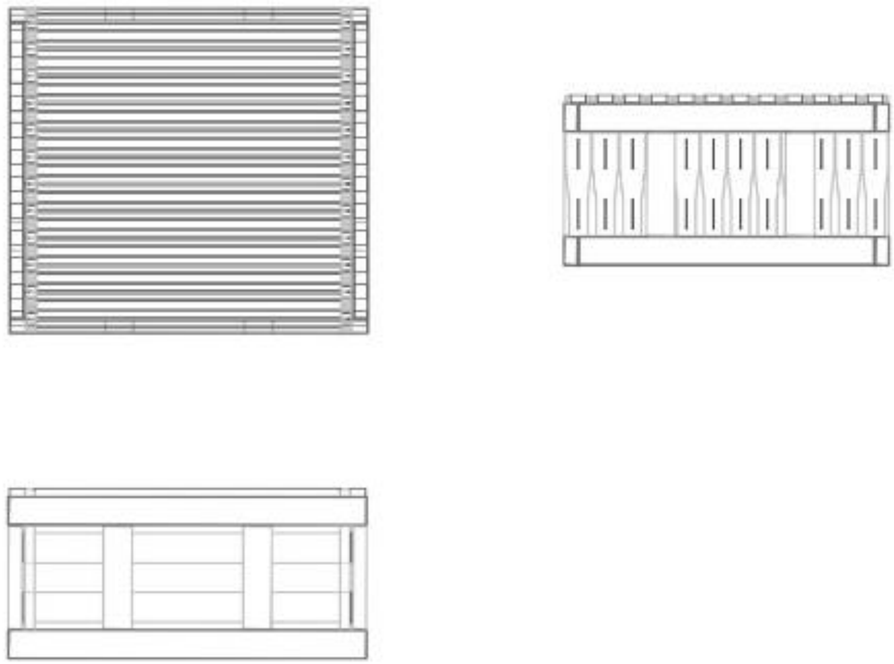


Figure 4.8.65 Orthogonal projection of the crate laden with the frames
Illustration by researcher, 2020

4.9 Production of the prototype with a manual of the RBH for apiculture.

4.9.1 Overview.

The prototype was used to:

- Check the technical feasibility of the RBH design to see if it will work as a physical object.
- Test the visual facets of the design by presenting them as they would be produced.
- Provide the opportunity to test, were pertinent, the RBH in three dimensions.
- Give the researcher and client the ability to visualize and handle the RBH concept, to get an idea of its physical presence and tactile qualities.

Since the prototype aimed to test particular aspects of a design solution, it was made so that those particular aspects were present and would be effectively evaluated to convey the idea of what the RBH looked like.

The prototype was produced through studio experimentation. That was through the production drawings generated in the previous objective which had to guide the researcher on every measurement to be observed while constructing the prototype. The working drawings indicated the different parts that formed the entire RBH and how all those parts were assembled together to form the whole RBH. Several tools and materials which were relevant in construction of the prototype was identified as well.

4.9.2 Making the prototype.

To generate a portable size of prototype of the RBH shown in figure 2.9.2.1, it became necessary to identify a scale which would resize the actual RBH. The scale of 1:10became the best scale because it reduced one meter to 10 centimeters which implied that the actual length of the RBH which was 7.7meters was reduced to 77centimeters, the width of the actual RBH which was initially 6meters was cut back to 60centimeters while the actual height of the RBH which was previously 2.5meters became scaled down to 25centimeters.

Having selected an appropriate scale to work with, several materials were identified. The materials included; Wood, cardboard, artboard, manilla paper and chopsticks. Several tools were also selected. The tools included; Hand saw, Jack plane, builder's rule, scale rule and pencils.

Owing to the size of the prototype, it was very important to select a structural material which would be firm and light, but also easy to work with. Firmness of the material would enable it to sustain its own load without collapsing and also make it possible to be handled and lifted without damaging it. Lightness of the material would enhance portability of the prototype thus make it possible to transport it from one place to another. Finally, a material that is easy to work with would reduce the hustle of seeking sophisticated tools and equipment for cutting and joining, thus the prototype would easily be made by use of simple cutting tools such as cutters and scissors.

Figure 4.9.2.1 The wall thickness of the lower part of the prototype.
Photo by researcher, 2020

There RBH consists of two basic components which include the sub-Structure (the part of the RBH that is to be constructed below ground level) and the super Structure (the part of the RBH that is to be constructed above ground level). To construct the prototype, it required a base upon which the RBH would seat.

The base of the prototype was expected to be strong because by it the entire prototype could then be lifted. A 40milimeter block bord was selected for that purpose. The base was also expected to capture the splash apron of the RBH. The base was made by technically constructing the outline of the splash apron on the block bord and cutting it out using a handsaw.

The sub-Structure of the RBH includes the footing and plinth. Since the footing and the plinth of the RBH would be totally submerged under the ground, it was not necessary to capture it in the prototype since it had no direct influence on apiculture but except to anchor the load of the RBH into the ground. The prototype therefore intended to capture the appearance of the RBH right from the superstructure.

The super Structure of the RBH include parts such as the floor, load bearing walls, doors and windows, ring beam and the roof

The floor slab was made by technically constructing the outline on cardboard and cutting it out using a cutter. The cut out formed the internal slab of the RBH. The cut-out cardboard was then covered with manilla paper of a choice color using wood glue to depict the floor finish of the RBH slab.

The walls of the RBH are 200millimeter thick because they are load bearing. In real setting, these walls would be constructed using burnt clay bricks. To depict their thickness in the prototype, wood such as block board and MDF would be the most appropriate due to their strength and firmness with good joinery. Such woods were however not used because they posed the challenge of hardship in workmanship such as cutting or trimming. They also appeared to be heavy and would make the prototype overall bulky. A better alternative was cardboard because it was light and easy to cut using a cutter. To achieve the desired wall thickness on a scale of 1:5, it required a lamination of about three cardboards to achieve a fair representation of walls. The cardboards were glued together using wood glue and clipped together using pegs till the wood glue was dry. The clipping together enabled the cardboards to dry together without warping off each other.

To create walls with door and window opening was much easier to cut each door or window opening on a single cardboard peace then redo the process for the next two pieces of cardboard before gluing them together. That gave a more even surface along the cut surfaces.

Having cut the desired walls, the next stage was to mount them on the base slab. Small drops of super glue were used to instantly stick the walls on the base slab. That was followed by smearing wood glue along the edges so as to strengthen the joints. The reason wood glue was not used alone was because it takes time to dry, and that would slow down the process of making the prototype. Superglue was always used in small proportions because it smudges the surfaces and is also more expensive as compared to wood glue.

The researcher wished that the apiculturists should have a better view of the interiors of the prototype for better visualization hence there was need to have a prototype that could be opened above the ring beam to expose the interior. That implied that the height of the walls would be cut at 2300 millimeters to form the lower part of the prototype then the construction would continue above that height.

Having constructed the walls of the prototype, it was necessary to enhance its realistic appearance as opposed to having it left as a monochromatic prototype. That tasked the researcher to develop finishes materials inform of A_3 paper printouts after which the best samples for the finishes could be selected and pasted on the structural parts of the RBH prototype.

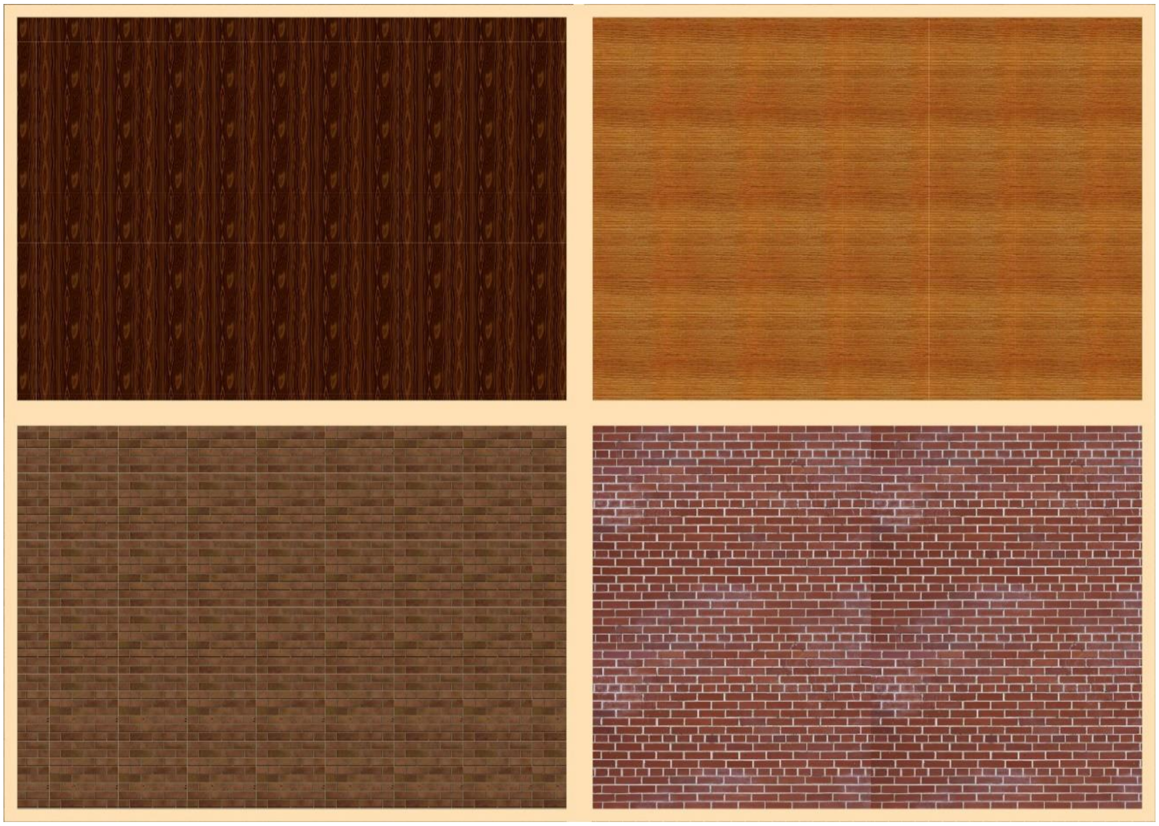


Figure 4.9.2.2 Samples of materials that were used as wall paper in the prototype.
Illustration by researcher, 2020

To generate each single material, it was important to first develop a design by the help of photography. A design was developed by cropping a photograph of an actual material using Adobe Photoshop, then the cropped design was imported to ArchiCAD program where it was scaled. The design was hence duplicated to form a motif that would represent the actual material on the prototype. The motif was later fitted on A_3 layout on a scale of 1:5. The layout was then saved as a PDF file to enable its printing from nearby printers. Those PDFs formed the templates which were reprinted on A3 art papers and so used as wall papers for finishing the prototype.

The roof of the RBH will be of iron sheets since it is not only locally available, but also affordable by apiculturists. The roof was therefore represented using cardboard on the prototype. The roof of the RBH will have an eave of about 500milimeters. That will help to provide sun shade to the walls of the RBH. That was well captured in the model by having the cardboard roof overlap 40milimeters away from the walls of the prototype.

The prototype did not require a constructed structural ring beam as no one would have the need to cut through it so that they may appreciate its existence. However, for the purpose of visualization, a finish in form of a wall paper was pasted on the region of its location for clarity on the prototype. The thickness of the ring beam was 200milimeter deep on the RBH, and that became 20mm on the prototype

The three Respondents independently suggested that they would be interested to have a prototype which could be easy for them to understand. The researcher therefore felt that it would be simpler to understand the prototype if it was constructed in a manner so as to allow someone to clearly view the interior. The researcher achieved that by having the prototype in three layers that could be manually separated. The first layer in the figure 4.9.2.1 below shows the interior of the RBH.

Figure 4.9.2.3 Cardboard structure and the interior development of the RBH prototype
Photo by researcher, 2020

The second layer of the RBH prototype as shown in figure 4.9.2.2 was aimed at showing how the truss of the RBH would be constructed and also show the details below the roof structure. That would help the builders to easily understand how to construct the roof of the RBH.

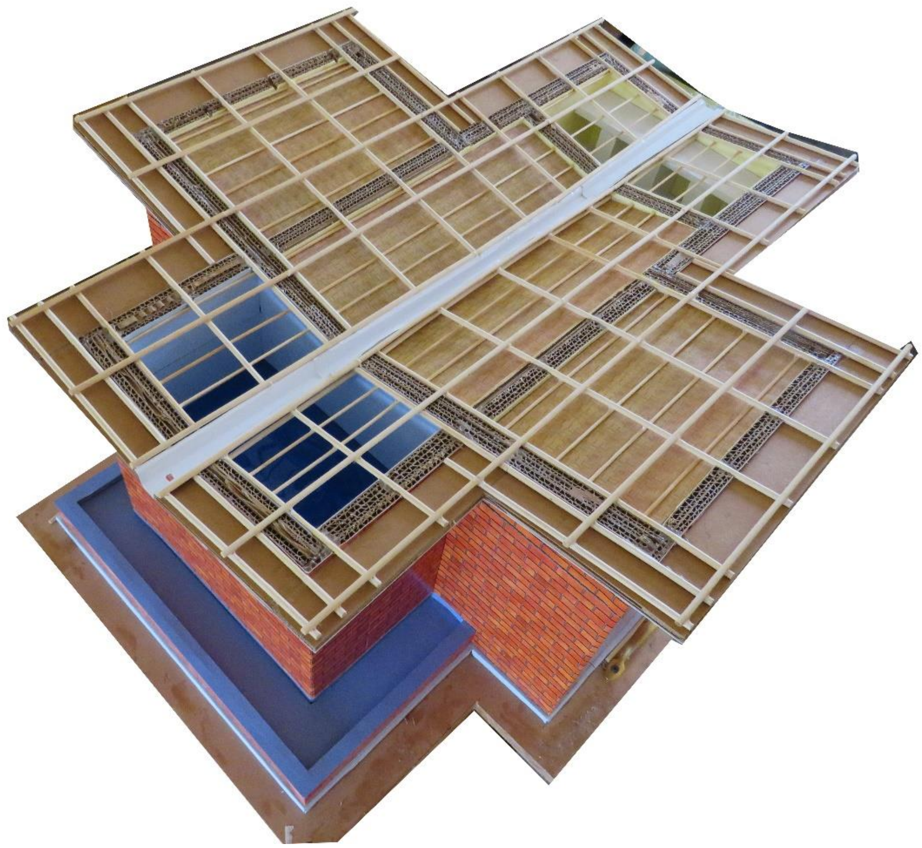


Figure 4.9.2.4 The roof structure and the drainage of the RBH
Photo by researcher, 2020

The final layer is the roof itself which is removable to allow one appreciate the roof structure below it. With such design of the prototype, the researcher is convinced that the apiculturists and the builders of the RBH should be able to understand the design of the RBH.

The design manual of the RBH was developed from the working drawings captured in section 4.2 of this chapter and will be an independent and independent entity attached to this report.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATION

5.1 Introduction

This chapter stages a discussion between the RBH versus both the local hives and the modern hives within Wild bees Apiculture farm in Sheema District so as to assess the level of performance in regard to the quantity and quality of honey produced. The discussion will be based on the views and concerns of the respondents in relation to the researcher's opinion. The effort to analyze the quantity and quality of honey produced in Sheema District will focus on the materials used to construct the beehives, the nature of hives themselves in their environment and their performance in relation to the quantity and quality of honey harvested.

5.2 Summary

Considering the materials that were used to make the local beehive, it was obvious that straw, reeds, grass and banana leaves which were used to make those type of beehives are very bio-degradable and that is why they could never last long. The risk of the hives collapsing even before the appointed time of harvest made apiculture very unreliable as bees would swarm away leaving behind no honey to be harvested. To resolve that, the materials that will used to construct the RBH such as the burnt clay bricks, wood and iron sheets are strong and are resistant to weather and are long lasting hence eliminating the chance of a beehives collapsing.

It was observed that both the KTB beehive and the Langstroth beehives suffered the fate of being stolen by thieves. Theft of honey itself by workers and rats was an unwelcome subject that was observed to threaten the quantities of honey harvested in the farm and none of the beehive type was compromised. The honey was easily stolen by workers because it was very easy to open the hives and get to the honeycombs without difficulty. Having observed the two forms of theft which included workers in the farm and rats, the RBH was designed in a manner so as to encase all the beehives in a lockable shell that could only be accessed by the rightful persons. The shell provided bee entrance which was customized for the bee size thus keeping away rats which threatened the security of honey in the hives.

That that will therefore ensure maximum protection to the honey thus resulting to increased volumes of harvest.

From the findings in section 4.4, it was observed that the local hives though cheapest, they provided the least quantity of honey which was attributed to its structure of less overall surface of attachment of the honeycomb constructed by the bees. This challenge was addressed in the KTB hive where the wooden bars on top of the hive provided a foundation upon which the honeycombs would be built. The challenge with the bars in the KTB hive was that the honeycomb freely hung on the bars upon which they are built hence become very delicate and sometimes break in in the process of inspection. This challenge in the KTB hive is well addressed in the Langstroth beehives where the honeycomb is built in a complete frame that even has binding wire for reinforcement of the honeycomb. The successful performance of the Langstroth beehive is the reason the researcher saw if fit to adopt the Langstroth frame in the RBH so as to benefit from its efficiency in the quantity of honey produced.

The local hive, the KTB hive and the Langstroth beehive are very efficient and affordable for small scale apiculturists who only need one or a few hives. But with the current demand of honey both nationally and globally which calls for many beehives, this approach of apiculture ceases to be economical. For apiculturists with intention to produce high yields of honey, the Langstroth beehive was observed as the hive of choice for its highest produce. The challenge of this hive was the cost, especially if the apiculturist is to procure many of them. Besides the high costs that would be incurred in procuring many of these hives, there is also the challenge of space limit as currently land is being fragmented into small portions and this cannot be overlooked because it did not show up in Wild Bees farm. Apiculturists may thus in future have not have sufficient space to install the numerous beehives. The RBH has addressed the component of cost by maximizing on the use of bricks which is cheaper instead of timber for the protective shell of the hives. The use of bricks not only minimizes the overexploitation of timber hence contributing to environmental conservation but also minimizes the high cost associated with the use of timber itself. Finally, the compact design of the beehives in the RBH minimizes space hence an apiculturist can successfully exercise large scale apiculture on a small piece of land so as to observe high volumes of honey within a small piece of land.

One of the challenges occasionally experience was the swarming of bees which was motivated by especially lack of water in the vicinity during dry seasons. To prevent this phenomenon, the RBH provides a water reservoir that feeds from storm water and can directly be administered to the bees in times of scarcity. That would greatly sail the bees through dry season as it has the capacity to store 6700liters of water hence having the potential to deliver 40liters of water daily for 5months and 2weeks. That will successfully sail them through drought.

The local hive suffered the most challenge of impurities which were associated with the nature of materials used to construct the hive. The clay and cow dung used to cover the hollow reed basket would easily find itself into the honeycombs through disintegration. The grass, banana fibers and reeds would also shortly succumb to weather by rotting and would soon have its fragments get to the honey hence having it contaminated, and as Chitalu, Garibay & Ssebunya (2011) had noted, such adulterated honey cannot enter the formal market chain except to be used for local consumption.

The KTB and Langstroth experienced minimal exposure to contamination as the wood was always intact and free from pollutants such as soil and decaying materials. The possible cause of contamination in these two types of hives would occur during harvesting when exposed to dust or rain.

The RBH, consist of wood that has been protected from weather by the brick walls and iron sheets hence totally eliminating the form of contamination experienced especially in the local hive. The fact that all the hives in the RBH have been sheltered from weather, also eliminates the chances of the honey being contaminated during harvesting due to poor weather such as rain or dusty winds.

The researcher also believes that the good thermal properties of brick would do a great job in controlling the environment under which the honey is stored in the chambers of the RBH by avoiding excessive heating and cooling of honey caused by the variation of weather.

To rapidly increase the quantity of honey produced in Sheema District, it would call for motivation of all potential apiculturists to participate in such a nobble course. It is at such a point that the researcher would register sympathy to most potential apiculturists who might not have resources enough to construct the RBH. The researcher is however convinced that with collective communal efforts, such challenge can be overcome by such potential apiculturists putting their resources together to construct the RBH.

5.3 Conclusion

In light of the discussion above, the challenge of low quantity and quality of honey has been addressed by the RBH by providing a clean environment to harvest honey which improves the quality of honey harvested, maximizes on small space with many beehives which in turn results to increased quantity of honey harvested, and finally, guaranteeing the bees and the beehives safety from thieves and vandals which contributes to increased quantity of honey harvested. The researcher is therefore convinced that the prototype of the RBH will enable the apiculturists visualize the RBH and understand it hence will be able to construct it with the help of the design manual.

5.4 Recommendations

1) Bee venom is becoming a lucrative business in the pharmaceutical industry as one gram sells at 50,000 UGX. This calls for advancing the conversation of the RBH to see how effective its design it could contribute to the exercise of venom extraction.
2) It is recommended that the apiculturists should avoid growing tall trees around the RBH as the leaves would liter the roof and block the gutter.
3) Oil based paints and any strong scented paints should be avoided in the RBH as they would drive the bees crazy.

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APPENDIX 1

IN DEPTH INTERVIEW GUIDE FOR BEE KEEPERS IN SHEEMA DISTRICT

1. **Opening**
   A. My name is Murunga Roger, a master's student in Kyambogo University, conducting a research on how to improve honey production in Sheema District. I considered it a good idea to interview you, so that I can be well informed and hence be in a better position to redesign a RBH for apiculturists.
   B. I would like to ask you some questions about your beekeeping practice, some experiences you have had with the type of beehive(s) you use, so as to understand your needs, desires and approach to beekeeping practice.
   C. I intend to use this information to design a RBH that will protect the bees, the hives and hence improved honey production.
   D. This interview will be able to take about 10-20 minutes. Are you available to respond to some questions at this time?

I would wish to begin by asking you some questions about the beehive design(s) that you have in your apiary.

2. **Body**
   A. To analyze the causes of poor quantity and quality of honey among apiculturists in Sheema District, Western Uganda.
      a) Which type(s) of beehives do you use and what is the estimated quantity of honey produced in each type per harvest season?
      b) Which materials are used to make the beehives?
      c) Where is the source of materials used to make the beehives?
      d) What is the life span of the beehive(s)?
      e) How do you inspect the beehive(s)?
      f) How do you prepare the honey before selling?
      g) How do you store the honey before selling?
      h) What challenges do you encounter in beekeeping in relation to the beehive(s)?

I will proceed by asking you yet some questions on ideas that could be helpful in designing a RBH.

   B. To develop designs of a RBH for apiculturists in Sheema District that prevents theft of honey and destruction of colonies.
      a) Which materials would you prefer for a RBH?
      b) Why would you prefer those materials?
      c) How easily available are those materials?
      d) What could be the solutions to the challenges you face with the current beehive(s)?

e) How could the solutions above be achieved in the RBH?
f) What are some of the functions you would wish to achieve in the RBH?

Last but not least, I will seek your views about the prototype with manual that I intend to develop for the RBH.

C. To produce a prototype of the RBH with a manual for apiculturists.
   a) What would be your response towards the prototype for the RBH?
   b) What would be your expectations as far as the design manual for the RBH is concerned?

Substantially, it has been a great delight finding out resourceful information about beehives from you. I kindly request that I may briefly summarize the information that I have recorded during this interview.

3. Closing

A) Your future plan about beekeeping is to_______________________________________

B) I greatly appreciate the time you gave in to this interview. Is there anything else you think would be helpful for me to know so that I can successfully design a much better RBH?

C) I should be having all the information I need. However, would it be alright for me to get in touch with you at home over the phone if I have any more questions? Thanks once more. I look forward to a positive outcome.

APPENDIX 2

OBSERVATION GUIDE

- Materials used to make the beehives.
- How the beehives are kept.
- Durability threats of the materials used.
- Safety threats of the beehives.
- Challenges of inspecting the beehives.
- Challenges of harvesting the honey.

APPENDIX 3

CONSCENT FORM

CONSENT TO AN INTERVIEW ABOUT APICULTURE

My name is Murunga Roger, a master's student at Kyambogo University, conducting a research on how to improve the quantity and quality of honey production in Sheema District. I considered it a good idea to interview you, so that I can be well informed and hence be in a better position to design a RBH for apiculturists.

I would like to ask you some questions about your beekeeping practice, some experiences you have had with the type(s) of beehive(s) you use, so as to understand your needs, desires and approach to beekeeping practice.

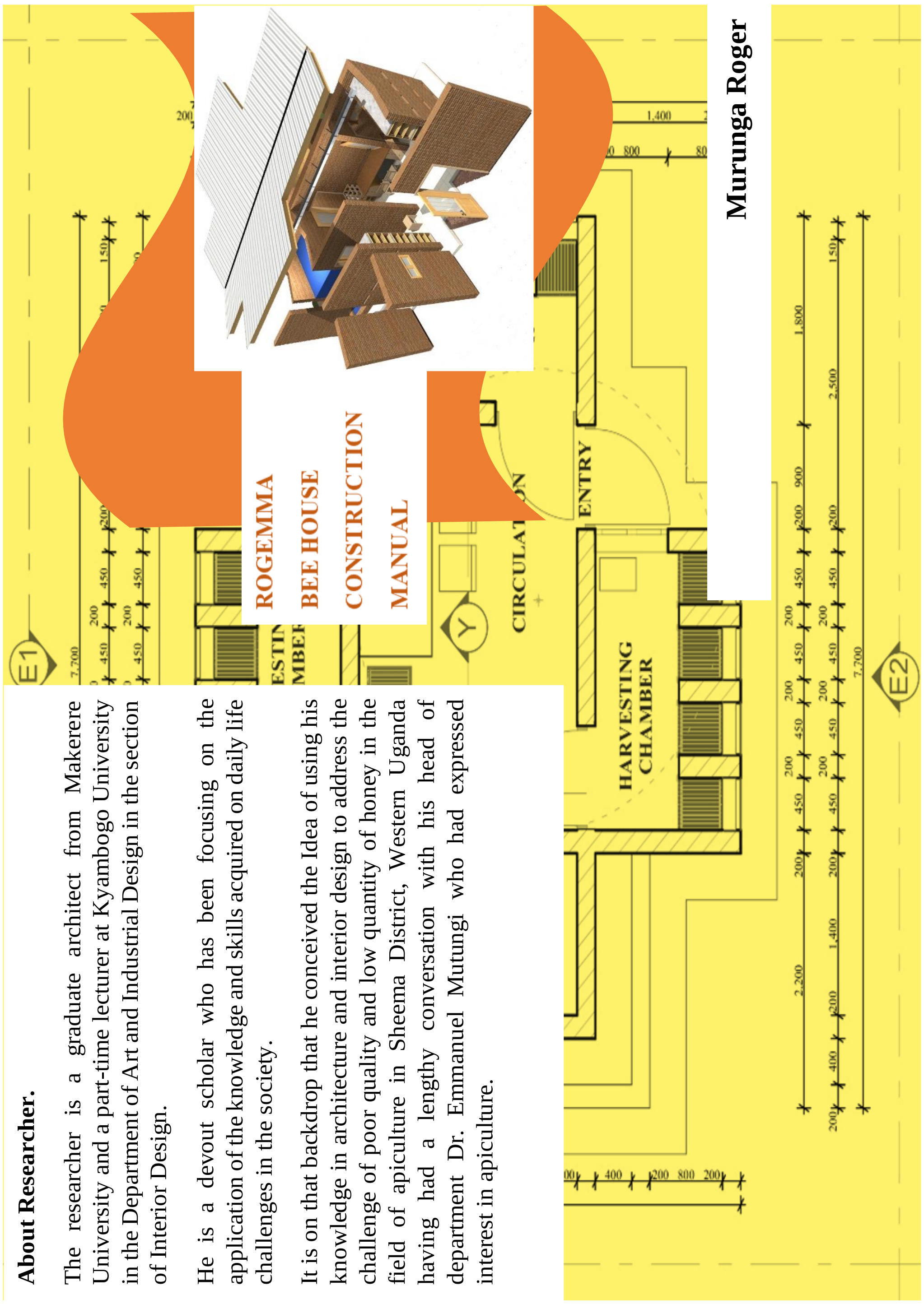
I intend to use this information to design a RBH that will protect the bees, the hives and and provide a hygienic environment for honey. You will be cited wherever the information you have given will used in this research.

I have read and fully understood the above information provided and I therefore consent to this interview.

Respondent Name: …………………………..Signature…………..Date…………………

APPENDIX 4

DESIGN MANUAL



An RBH is a masonry shell of 28 m2 overall floor area with three harvesting chambers, each consisting of twelve inbuilt sub-chambers. Each sub-chamber has one brooder and two suppers (honey stores) and all of them consists of only the Langstroth frames and the brooder having a coffee mesh above it to exclude the queen from the supers. This implies that the whole bee safe has a total of thirty-six brooders and seventy-two supers for collecting honey. The bee safe also consists a central space that is used for extracting honey from the Langstroth frames and also is a storage for equipment used in harvesting of honey. Finally, the RBH has a water tank that that is fed by rain and supply water during dry seasons when streams and swamps are dry.

This manual contains the details for construction and operation of the RBH. Welcome to this method of apiculture that will guarantee you not only safety for your honey and bees, but also increased honey production.

CONTENTS

GENERAL PRECAUTIONS

The construction of the RBH may require specialized skills and it may be often be subjected to the building control regulations.

Despite the fact that the honey bees are wild insects, they are very organized and therefore their RBH need to be treated with care and precaution.

Get educated: There are skills that one needs to know so that they can safely and successfully be able to construct the RBH. It is therefore recommended that the apiculturist should either learn some construction skills or liaise with local builders so that they can register success.

Follow the guide lines: Where's you have been provided with several rules and regulations that will govern the construction of the RBH, it is possible that in some jurisdictions, the construction of such a structure may be restricted by the local authorities.

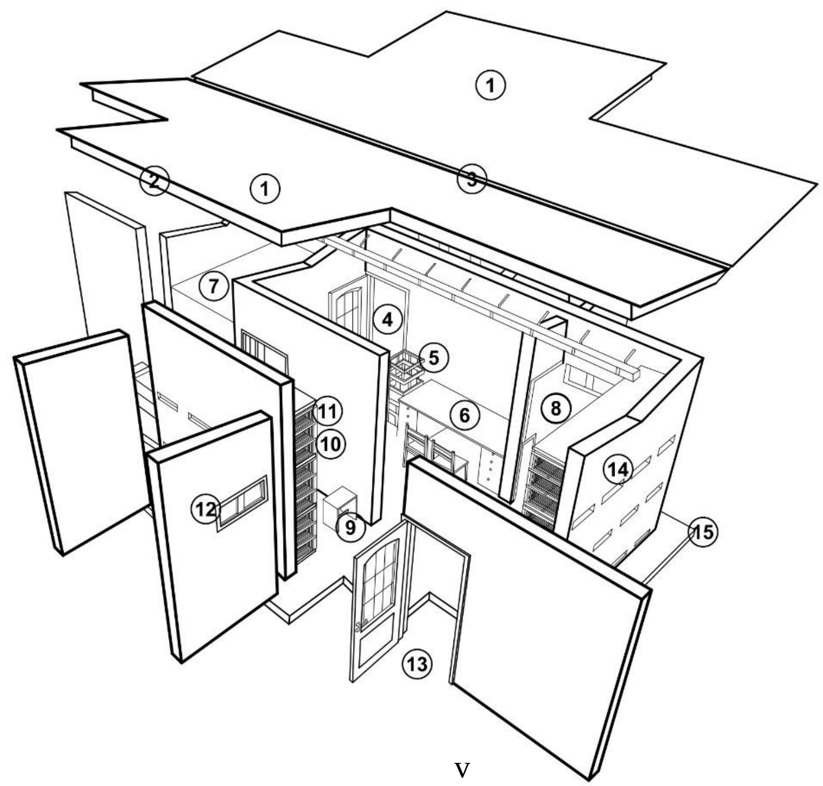
Understand the risks: In as much as bees are very beneficial to humans, don't forget that they not only sting humans and animals! Therefore, ensure that you understand the risks so that you may take precautions.

Take Responsibility: There is a wide community of apiculturists around the nation and therefore to register commendable success, it is very critical for each one to act responsibly and ensure the safety of the humans and animals around us. Incase you have neighbors, inform them and educate them as well.

SAFETY PRECAUTIONS

Aware that the bees sting and that being a menace, it is very important to ensure that all the doors and windows especially those that surround the extraction space are well sealed from the bee's penetration when they are closed. That would allow other activities to proceed within that space with a subdued hazard of the bees.

COMPONENTS OF THE RBH



1 RBH roof

2 Fascia board

3 Gutter

4 Internal door

5 Langstroth frame crates

6 Extraction table

7 Water storage tank

8 Harvesting chamber

9 Harvesting stool

10 Brood box

11 Super

12 Harvesting chamber window

13 Entrance and exit to the RBH

14 Entrance and exit for the bees

15 Splash apron

List of part names

Extraction chamber-This is the space where honey is extracted from the frames.

Harvesting chamber- This is the space where honey is harvested from the bee hives.

Brooder -It is the part of the beehive that hold the combs where the bees lay eggs. These eggs hatch into bee larvae, which then pupate and turn into bees.

Super - The part of the hive that hold combs where the bees deposit honey.

Frames-These are the boxes on a bee hive that the bees store most of their honey in.

Extraction table-This is the platform where honey is extracted. It also acts as a storage of harvesting equipment.

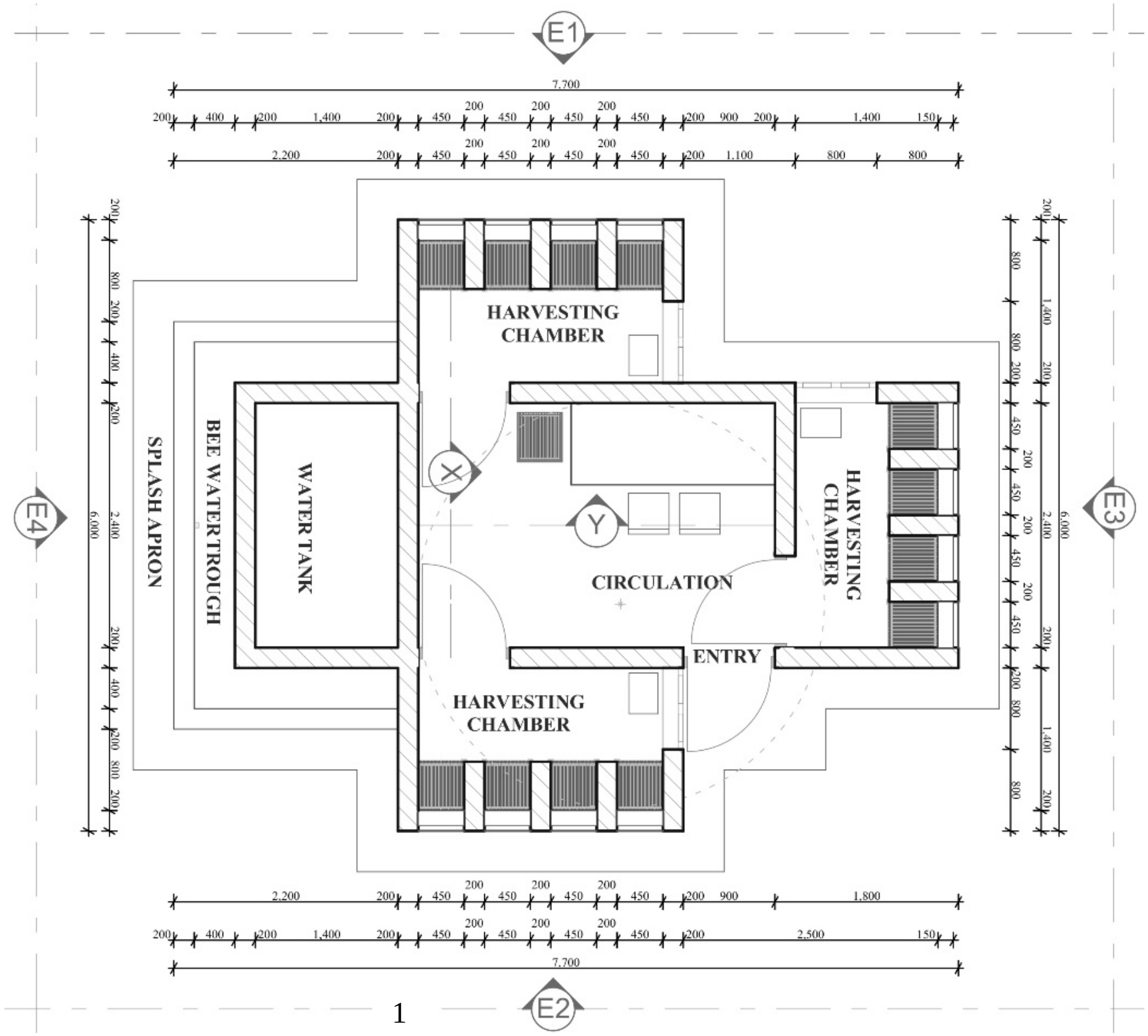
Water tank- This is an enclosed masonry wall that collects rain water and stores it for use during times of shortage.

Water trough - the open shallow platform at the base of the RBH around the water tank. It provides the bees with water.

Front of RBH - The side of the RBH where people enter into and from the RBH.

WORKING DRAWINGS

THE PLAN



Notes:

All the dimensions on the drawings are not to be scaled.

The floor finish shall be on 150mm thick concrete slab on gauge 1000 d.p.m sheet on 50mm thick marram blinding on 300mm well compacted and anti-termite treated approved hardcore.

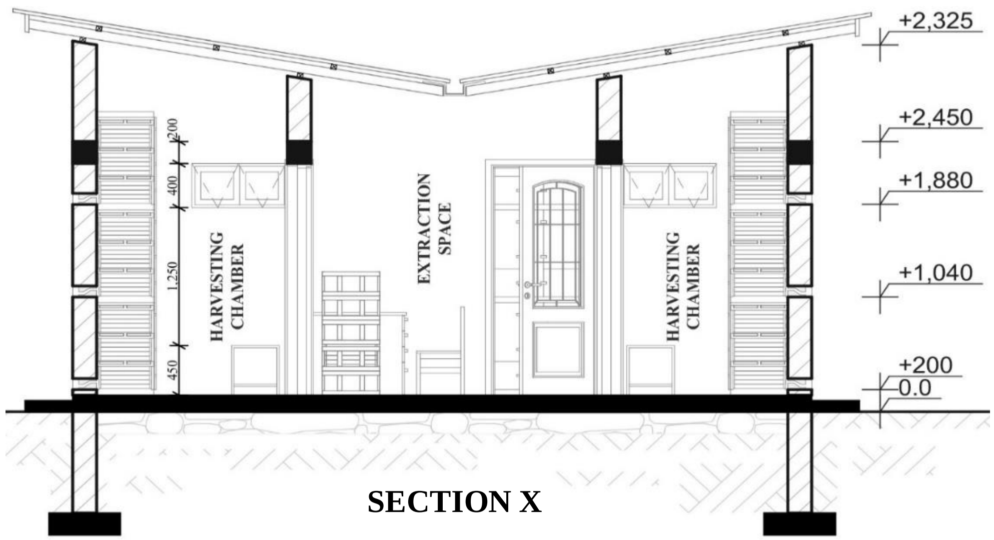
The above specification is subject to variations depending on the context or the availability of local materials thus the apiculturist may be required to seek the advice of the local builders in selection of materials.

Internal floor and wall finishes will be done in accordance to the client's approval. Aggressive colors such as red should be avoided as they provoke the bees to hostility

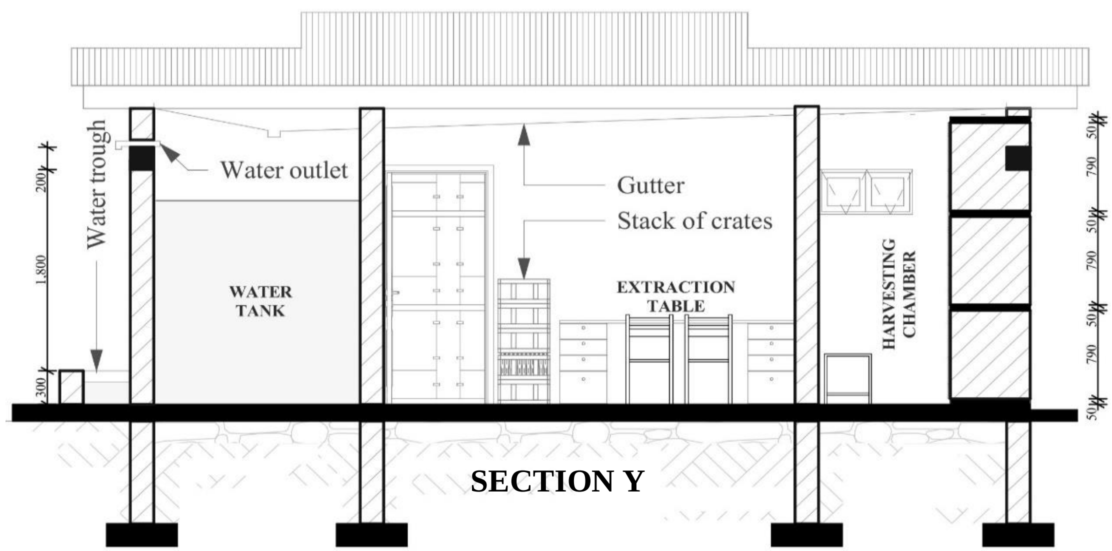
The 400mm wide splash apron will be treated with waterproof cement to keep away dampness at the base of the RBH.

2

THE SECTION



SECTION X



SECTION Y

3

Notes:

The iron sheets shall be on 75x50mm thick timber purlins on 100x50mm timber trusses at 10degree roof pitch.

The external walls shall have a 200x200mm RC ring beam that will move around the entire shell of the bee house.

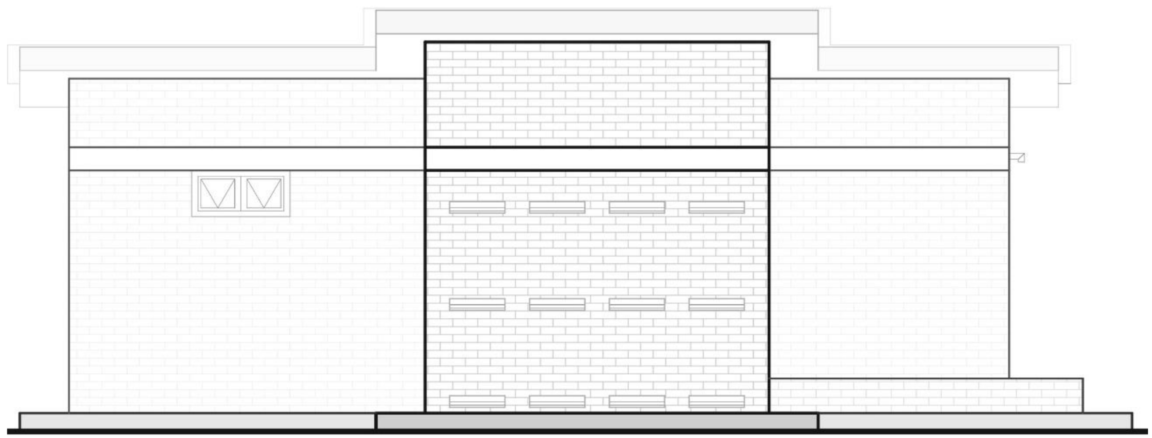
Door openings within the internal walls will have 200x200mm RC lintels above them.

The internal walls of the water tank and the water trough will be treated with waterproof cement.

The foundation shall be on 200x 600mm RC footing on weak concrete blinding. Proper drainage should be ensured around the bee house to prevent water clogging.

4

THE ELEVATONS



ELEVATION 1

ELEVATION 2

Notes:

All the external walls may or may not have a wall finish.

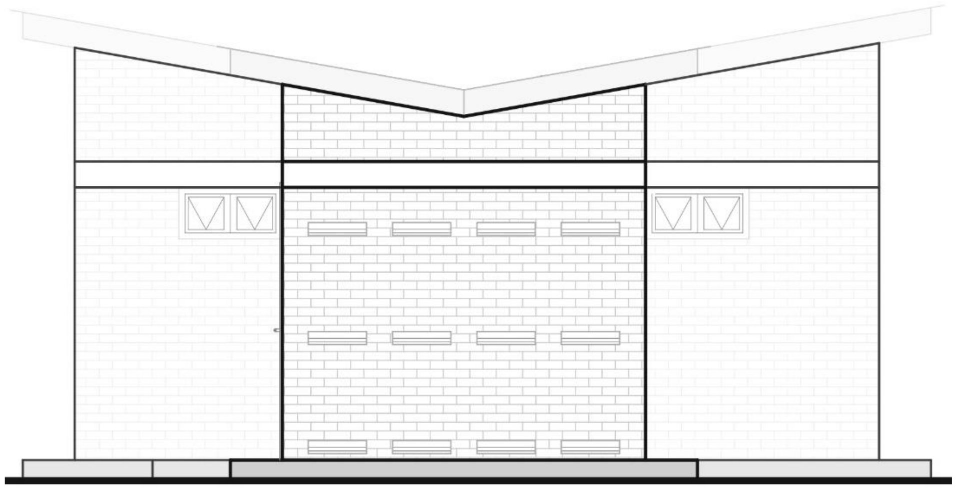
The water tank shall be oriented to the Eastern side where necessary as that would keep the bees from the afternoon glaring and scorching sunshine

The entrance door shall be steel casement with bugler proofing. In accordance to the door schedules on page 9

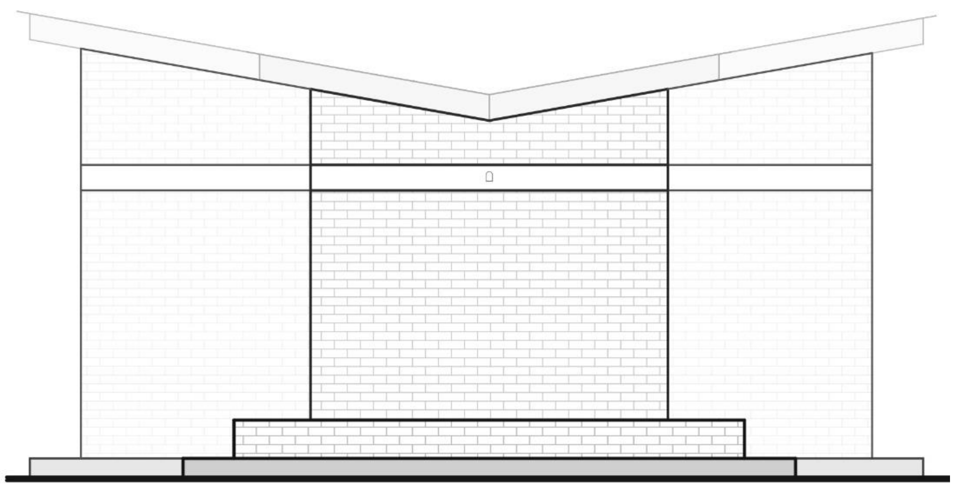
All the internal doors to the harvesting chambers will be solid flush core doors according to the specifications on page 9

The bee entry profile shall have a profile that stops water from entry into the brooder as illustrated by the detail on page x

THE ELEVATIONS



ELEVATION 3



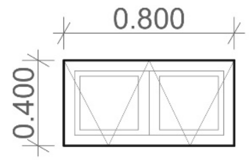
ELEVATION 4

Notes:

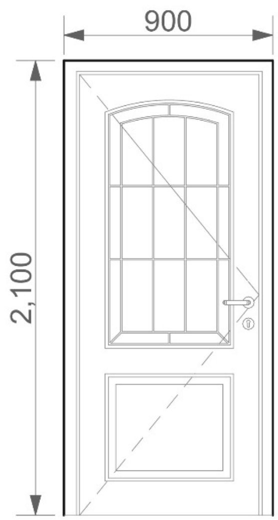
The water thank shall be installed with an overflow pipe to drain the tank in the event of excess rain water.

An openable access shall be provided above the beam for the purpose of inspecting and cleaning the water tank internally.

DOOR AND WINDOW SCHEDULES

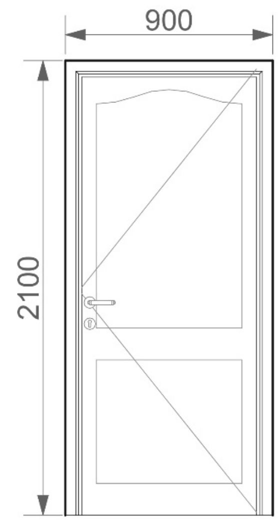


Steel casement window



Steel Casement door

External

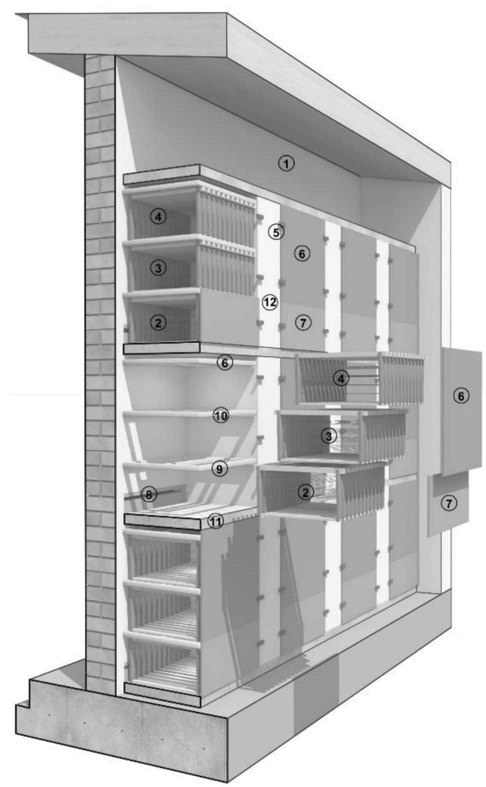


Solid Core flush door

Internal

DETAILED DRAWINGS

INSTALLATION OF THE FRAMES TO FIT IN THE CHAMBERS.



1 Storage

2 Brooder

3 1st Super

4 2nd Super

5 Stopper

6 Suppers' lid

7 Brooder's lids

8 Entry and exit for bees

9 Queen excluder frame fixed wit coffee mesh

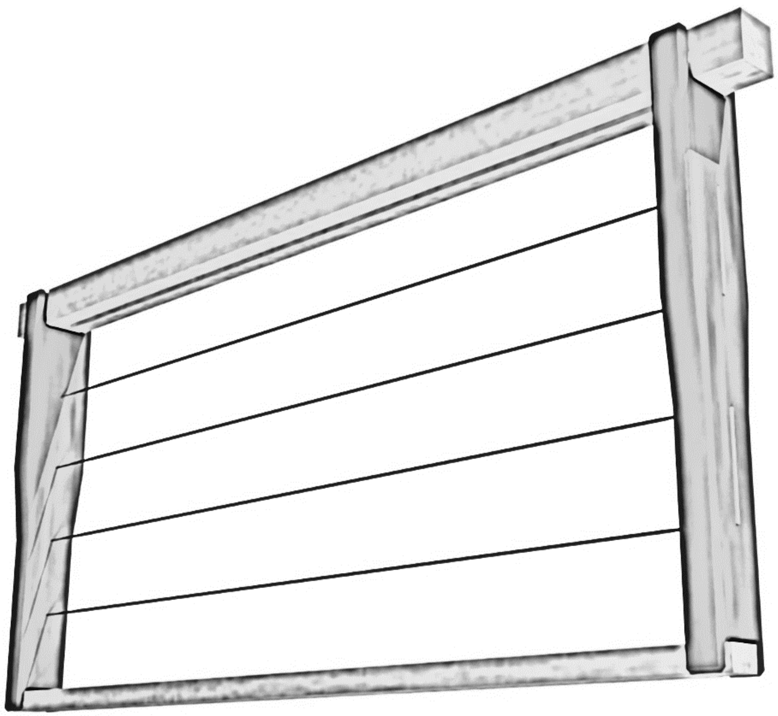
10 Frame separating the 1st Supper and the 2nd supper.

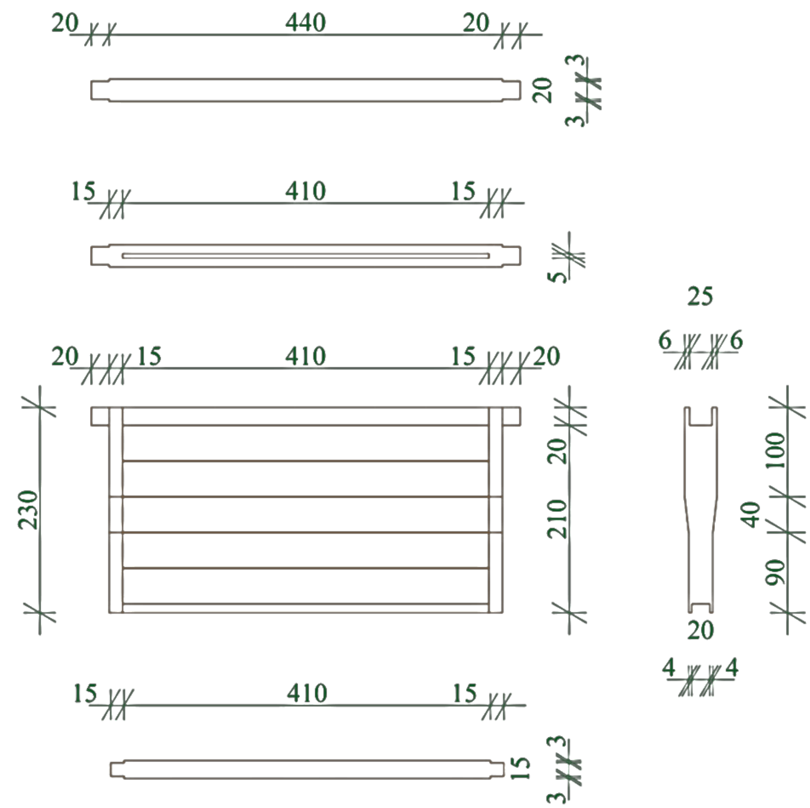
11 100mm thick slab

12 200mm thick brick wall.

THE BEE HIVE FRAME

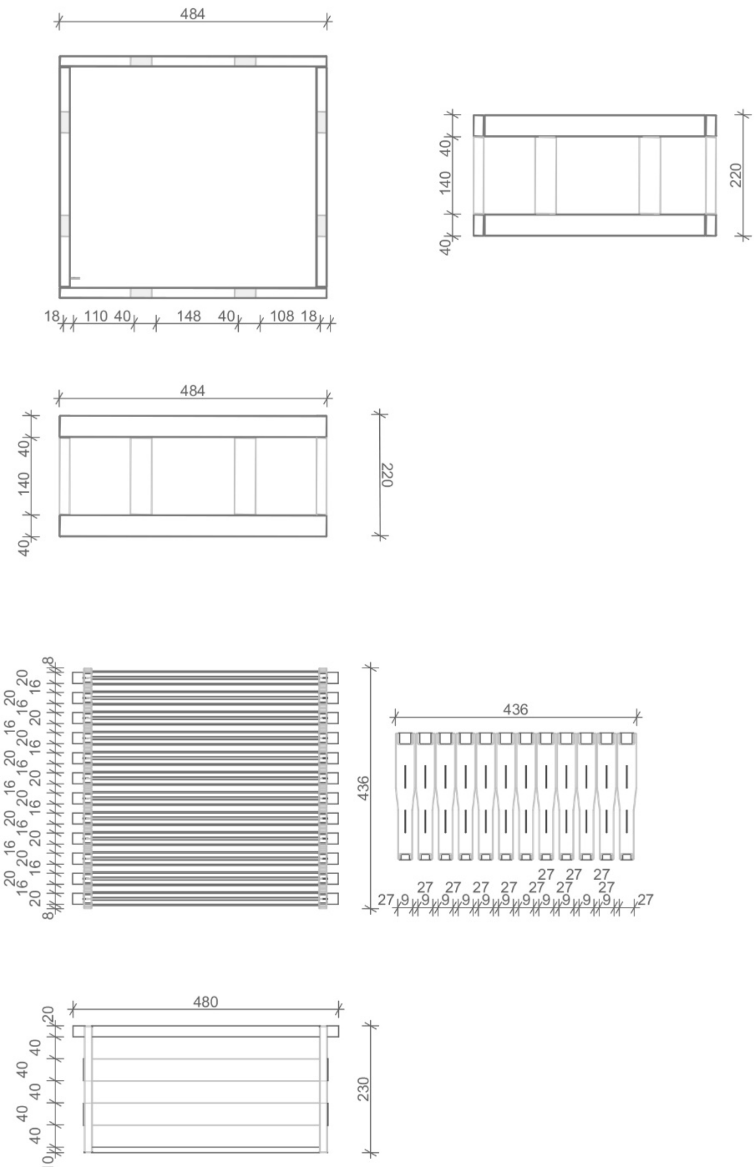
The beehive frame shall be made out of wood. Eucalyptus tree is recommended because not only of its availability but also its durability. Timber should be well seasoned before sawing them into the frames to avoid warping and twisting of the frames.





The four wooden bars are held together using nails not exceeding one inch as they would cause some bars to split. The same nails can be used to create the small openings within the sidebars so that the binding wire could be easily be fitted through. The binding wire should be tightened well to provide firm support for the honeycombs

THE HIVE AND THE CRATE



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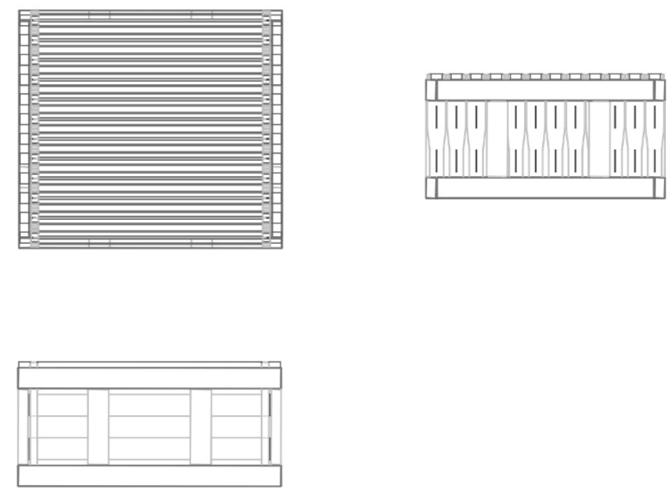

THE HIVE ENTRY/EXIT