REINTRODUCING HEMP (RONGONY) IN THE MATERIAL PALETTE OF MADAGASCAR:
A STUDY ON THE POTENTIAL OF HEMP - CLAY COMPONENTS AND ITS IMPACT ON SOCIAL AND ECOLOGICAL COMMUNITIES.

A THESIS PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE MASTERS OF ARCHITECTURE AT RHODE ISLAND SCHOOL OF DESIGN, PROVIDENCE, RHODE ISLAND, USA.

BY HENINTSOA THIERRY ANDRIANAMBININA - 2023
“MANANKAREN-TSALASALA, MANAO KITAMBY RONGONY” MALAGASY PROVERB

This Malagasy proverb translates into English “Modest wealth, to make hemp waist cloth”. Traditionally, the wearing of hemp clothes was common in the Ankaratra region of Madagascar, but elsewhere it was a sign of poverty as discussed in the proverb above, in which slaves wore coarse raffia cloth.
Abstract

When mentioning the word hemp, especially in the local language of Madagascar, the literal translation does not set it apart from marijuana, as they are both called “rongony” - creating the stigma around hemp as the negative stereotype of marijuana. However, the material has been used by the ancestors of Madagascar, as well as across cultures, in its fibrous form to produce fabrication like textile goods and packaging. During colonization, the prohibition of hemp intensified, and since then, any activity related to either of these plants is prohibited and will end in severe punitive measures. This thesis explores the strengths and sustainable properties of hemp as a building material, and how it can help empower local communities in Madagascar, through reconnecting with an ancestral and traditional plant while also combining traditional Malagasy architectural practices in construction (primarily brick making, biomimicry, and weaving). Looking at hemp in the material palette of Madagascar gives rise to the question: how hemp can help support and innovate Malagasy communities?

Key Words: Madagascar, hemp, clay, indigenous science, taboo, stigma, biomaterial, eco-construction, bio-inspired design, biomimicry, sustainability, nature based, biobased, regenerative, community based, local.
ABOUT THE AUTHOR

Thierry Andrianambinina is a multidisciplinary artist with an academic background in biology and pharmacology. He also identifies as an indigenous and African researcher from the island of Madagascar, aiding in his passions and focus of indigenous science and emphasizing designs at the local level. His prior experiences and knowledge have greatly shaped his design initiatives such as bio-inspired design, creating with the community, and innovative solutions that are sustainable and collaborative in nature. Much of his work tries to explore and challenge the many crossroads of the architectural norms and other disciplines, from art to technology.

SALAMA E!
(Eng: HELLO!)
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In loving memory of my grandfather, the one who introduced me to the world of construction through his skills and knowledge. This thesis is dedicated to him.

He was a farmer, a builder and my best friend. His skills had him involved in the team in charge of building large infrastructure (schools and university, housing, administrative buildings, etc.) during the post-colonial era of Madagascar. I was honored to have graduated from the college that has his handprints.
INTRODUCTION:

WHEN I WAS A YOUNG BOY, MY GRANDFATHER TAUGHT ME THE WAY OF LIFE IN THE COUNTRYSIDE OF MY HOMETOWN OF ANTSIRABE, MADAGASCAR, WHERE I LEARNED HOW TO LISTEN TO THE LAND AND TO OUR ANCESTORS THAT ARE OFTEN CONSIDERED INTERCHANGEABLE OR AS ONE COMMUNITY. HOWEVER, MY GRANDFATHER ALSO TAUGHT ME THE VALUE AND IMPORTANCE OF RESPONDING TO NATURE THROUGH CREATING AND DESIGNING WITH ONE’S HANDS. HE WAS A SKILLED MASON WHICH INSPIRED MY PASSIONS IN ARCHITECTURE, AND HOW OUR LOCAL MALAGASY TRADITIONS TRANSFORM OUR LIVED EXPERIENCES AND ARE GREATLY INFLUENCED BY NATURE, OUR ANCESTORS.

DURING THE SUMMER OF 2022, I ATTENDED A HEMP WORKSHOP AND WAS DRAWN TO THE PROCESS OF MAKING HEMPCRETE WALLS FOR THE BUILDING INDUSTRY. ONE SECTION OF THE WORKSHOP INTRODUCED ANOTHER WAY OF USING HEMPCRETE WHICH IS MAKING BLOCK/BRICK INSTEAD OF A CAST IN PLACE WALL WHICH MADE ME NOSTALGIC OF MALAGASY ARCHITECTURE IN BRICK MAKING WITH CLAY. THIS PRACTICE OF INDIGENOUS KNOWLEDGE EMPHASIZES THE SCIENCE, SKILLS, AND PRACTICES THAT ARE UNIQUE TO A PARTICULAR CULTURE OR COMMUNITY. WHEN TASKED IN CHOOSING A TOPIC FOR A MASTER’S THESIS, I HAD A LIGHTBULB MOMENT. I DID NOT KNOW EXTENSIVELY ABOUT HEMP AT THE TIME AND ITS USES IN CONSTRUCTION, BUT THE MORE I READ, THE MORE I WAS ENTICED TO LEARN AND EXPLORE THE POSSIBILITIES OF THIS PLANT MATERIAL. THE HANDS-ON PROCESS AND METHODOLOGY I USED DURING THIS THESIS WORK HAVE ENABLED ME TO GAIN VERY THOROUGH AND BROAD KNOWLEDGE ON THIS MATERIAL, ESPECIALLY ITS POTENTIAL AS A SUSTAINABLE BUILDING MATERIAL. I ALSO HAD THE CHANCE TO EXCHANGE WITH OTHER ORGANIZATIONS AND BUSINESSES WORKING WITH HEMP IN DIFFERENT FIELDS AND DISCIPLINES, WHICH GAVE ME DIRECT CONNECTIONS AND NETWORKING THOSE CONTRIBUTING TO THE RESEARCH AND KNOWLEDGE OF HEMP. I HAVE ENJOYED EXPLORING NEW POTENTIALS FOR HEMP AS WELL, BRINGING EARTH AND MOST IMPORTANTLY MY CULTURE INTO THE TOPIC. I SEE THIS THESIS WORK AS AN INVALUABLE GAIN OF PERSONAL KNOWLEDGE THAT I WANT TO CONTINUE DEVELOPING AND IMPLEMENT IN MY FUTURE PROFESSIONAL WORK. HEMP HAS NOW TAKEN ROOTS AS A PASSION OR SOURCE OF INSPIRATION TO CHALLENGE WHAT BIOMATERIAL MEANS ACROSS CULTURES AND HOW IT CAN BE APPLIED.
Hemp, or also referred to as industrial hemp, is an annual plant belonging to Cannabis Sativa species, while also being one of the oldest or most ancient crops in the world and observed across cultures (Commere 2022, 20). It can be dated as far back as 2800 BC in China, in which records indicate it was used primarily for fibers (Commere 2023; Wagner 2015). Some resources even document the material being used for centuries, dating even further back as early as 10,000 BC, especially for fabrication and binding.
Hemp (Rongony) in Madagascar

Historical records indicate that hemp, or referred to in the local Malagasy language Rongony, was introduced and transported to the island of Madagascar around 1100 A.D. (Warf 2014). This proves that this was an ancient material and that it is not a new plant that requires introduction to the country. The material was used by Malagasy ancestors due to its fibrous form to produce fabrication like textile goods and transporting/packaging items. During the 1800s, through economic trade with the United Kingdom, the leaders of Madagascar permitted the cultivation of hemp as an exportation product to the United Kingdom. The plant thrived especially well in the central highlands of Madagascar, due to both beneficial environmental conditions (ideal climate and soil) as well as in part to the in-depth knowledge of Malagasy farmers who practice season crop raising (Campbell 2012). However, during colonization, the prohibition of hemp intensified as it was commonly misidentified with recreational cannabis, and since then, any activity related to either of these plants is prohibited and will end in severe punitive measures.

Approximately 75% of Madagascar is made up of farmers who are also stewards of the land and protect the endemic biodiversity of Madagascar, in which 90% of its species, both fauna and flora, are found nowhere else in the world (Harvey et al. 2014). Additionally, not only do farmers make up a majority of the island and a large part of Malagasy history, the art of handcraft also has a large presence on the island. Handcrafting like weaving and fabrication with fibers represent a direct connection to past lifeways and a cultural wealth of the island. Such traditional practices provide a large secondary source of income for farmers and families in times of need (Fee 2012). Rongony symbolizes a hybrid of traditional material, ancestral knowledge, craftsmanship, and regenerative agriculture that could be used in building methods.
HEMP IN THE PRESENT - TO BE OR NOT TO BE MARIJUANA

ALTHOUGH HEMP DOES FALL UNDER THE SAME FAMILY AS RECREATIONAL CANNABIS, IT IS NOT TO BE CONFUSED AS IT CONTAINS LESS THC THAN ITS COUNTERPART (WAGNER 2015). HEMP IS A DURABLE, HARDY, AND AN EASILY ADAPTABLE PLANT, AS IT CAN SURVIVE IN VARIOUS CLIMATES AND GROW AT INCREDIBLE RATES.

MORPHOLOGY

IN ORDER TO PARTICIPATE IN THE KNOWLEDGE DEVELOPMENT AND DISMANTLE THE STIGMA AROUND HEMP, IT IS IMPERATIVE TO START WITH THE MORPHOLOGICAL COMPARISON WITH MARIJUANA. THE MOST NOTICEABLE DIFFERENCE IS ON THE SIZE OF THE PLANT. HEMP IS TALLER AND ITS LEAVES ARE THINNER. ON THE OTHER HAND, MARIJUANA RESEMBLES A BUSH AND IS MOSTLY KNOWN FOR ITS PSYCHOACTIVE EFFECTS.

CANNABIS SATIVA
• GROWS IN MOST CLIMATE
• NO PSYCHOACTIVE EFFECTS

CANNABIS INDICA
• WARM AND HUMID AREA
HEMP AS A BUILDING MATERIAL

HEMP IS A VERY STRONG FIBER, AND LARGELY KNOWN AS A GREAT MATERIAL FOR INSULATION. DUE TO ITS DURABLE FIBERS, ITS NATURAL AND BIOLOGICAL STRUCTURES HELP IT ABSORB MOISTURE 20% OF ITS WEIGHT AND ENACT AS A NATURAL FILTER (COMMERE 2022, 16; STANWIX & SPARROW, 2014). HEMP FIBERS, SHIV AND STALK, CAN CREATE BUILDING MATERIALS LIKE INFILL OR BATT INSULATION.

HEMP TRANSFORMATION: CULTIVATION TO PRODUCTION

NOW THAT WE HAVE DISTINGUISHED THE DIFFERENCE, THAT HEMP IS NOT MARIJUANA, IT’S IMPORTANT TO LOOK INTO THE PROCESS OF TURNING THE PLANT INTO A BUILDING MATERIAL. HEMP IS HIGHLY RESILIENT AND AFTER HARVESTING THE PLANT IT GOES THROUGH THE PROCESS OF DECORTICATION WHERE THE FIBER IS SEPARATED FROM THE STALK. AFTERWARDS, THE HURD OR SHIV IS OBTAINED FROM THE STALK AND MIXED WITH A BINDER (LIME OR CLAY IN MY CASE FOR THESIS STUDIES) IN ORDER TO PRODUCE VARIOUS BUILDING MATERIALS SUCH AS HEMP WALL, BRICKS, AND/OR PANELS. AS DISCUSSED PRIOR, IT CAN BE TRANSFORMED INTO BUILDING INSULATION.

PERFORMANCE/PROPERTIES (REF: HEMPCRETE)

- NATURAL MATERIAL
- FIRE RESISTANT
- PEST AND ROT RESISTANT
- MOLD RESISTANT
- THERMAL AND ACCOUSTIC REGULATOR
- LIGHTWEIGHT
HEMP PRODUCTION PROCESS

HARVESTING

DECORTICATING

MIXING

LIME

SPRAY

HEMPCRETE WALL

CAST IN PLACE

PREFABRICATION

BLOCK FORMING

FIBER

INSULATION

Seed

Oil

Food

Fuel

Leaf

Mulch

Medicine

Flower

Medicine

Hurd

Mulch

Insulation

Fiberboard

Fiber

Paper

Textile

Insulation

Root

Medicine

Compost

2-4 months

6-15 ft

source: Manual of Biogenic House Sections, Paul Lewis, Marc Tsurumaki, David S. Lewis
Integrating Agricultural System

The farmers are the main stakeholders in the whole process. Not only do they make up the vast majority of the population of Madagascar, roughly 75% (Harvey et al. 2014; Barrett et al. 2004), they also have acquired the skills required for the local building industry (Fujisaka 1989). Consequently, they’re the center for the local building industry and innovation as they could be involved in each step of the production process from planting to construction. By having smallholder Malagasy farmers involved in this circular model would give them more control and coping strategies to address the vulnerability and impacts of climate change like crop losses, rebuilding homes with localized materials, and income shortage. (Rakotobe et al. 2016).
Hemp as a plant is not meant to be monoculture. The ideal agricultural system would grow it through a cooperative process with farmers included in the process, a community based approach. It will sustain the supply especially in terms of quantity but also not cripple the main crop which feeds the farmer’s household (Barrett et al. 2004; Tremann et al. 2003). The cultivation process could happen during off season and that will leave/prepare the soil for the main crop. Indeed, the benefit of planting hemp is that it has the ability to fertilize/provide aeration to the soil due to its deep roots system. Hence, hemp is the ideal rotation crop (la culture du chanvre, François Desanlis.).
WHY CLAY?

HEMP AND CLAY COMING TO PLAY

Using earth in construction has been largely observed across all cultures and throughout human evolution, making it one of the oldest materials in traditional building methods and materials (Commere 2022, Minke 2013). Earthen structures, especially clay, are largely locally available and affordable, making it widely preferred to implement in building communities. According to Commere and Vyncke et al., roughly one third of the world’s population lives in earthen structures, and it is suggested to have at least 15% clay content in soil to be used in construction (Commere 2022, 15; Vyncke et al. 2018).

Clay was chosen as a binder for this thesis due to the location of Malagasy communities, in which the island of Madagascar is largely composed of red lateritic soils hence giving the infamous name the “Red Island” (Kaufmann 2008, 14; Bergsmark 1927). Clay is also largely an ancestral material, like hemp, and has been used throughout Malagasy history and for various purposes, one primarily being for construction material (Grifa et al. 2021; Crossland 2014; Personal Obs). The wide availability of the material would allow the country to capitalize on the available material, which is tied to local and traditional knowledge that has been inherited from clay and its ecological properties (Grifa et al. 2014). It was abundantly clear to include these aspects within the decision making processes for the thesis.
THESIS OBJECTIVES

This thesis aims to highlight the potential of hemp, specifically hemp-clay, as a regenerative and sustainable building component. A focus lies on hemp’s biological structure and ability to adapt which was discovered through hands-on observations and form finding experiments. The aim of my research is to try to dismantle the stigma on hemp in the material palette of Madagascar and give rise to the question how hemp as a material can innovate Malagasy communities. By writing and applying an indigenous lens to hemp and at the local level, I hope to shed a different light on this material moving away from a westernized post-colonial canon/framework. The information prior (both scientific and personal), inspired the goal of this thesis to explore the versatility of the material through 3 different forms that can be applied or adapted to the Malagasy culture and landscape.

RESEARCH QUESTIONS.

1 - How can indigenous knowledge be incorporated into the development and application of biomaterials? Additionally, the inverse how can biomaterials be used to preserve and promote indigenous knowledge?

2 - What are the ethical and cultural considerations that need to be taken into account when working with indigenous communities on biomaterial research?

3 - Could clay be a good binder substitute, especially for countries like Madagascar, and what is the potential of hemp/hemp-clay environmental performances/impacts?
DELIMITATIONS:
The scope of this thesis is to establish a clear connection of hemp with clay, two nature or biobased materials. The work is preliminary due to time limitations and resource restrictions, giving foundational concepts to be explored at a later time; like exploring additional biobased materials to be incorporated with hemp or going into more in-depth research and/or tests of hemp in other forms or applications (e.g. insulation, paneling, flooring, etc). This thesis investigates the characteristics of hemp and how it can impact communities both socially and environmentally. The research and prior knowledge are obtained from a Malagasy, French, and U.S. context, which sets the architectural background of the thesis.

IMPLICATIONS
The implications of my research are significant, as they highlight the importance of working with indigenous communities in the development and application of biomaterials. By taking into account the unique needs and preferences of different communities, biomaterials can be developed that are more effective and culturally appropriate.
INTENDED AUDIENCE.

This Master’s thesis challenges westernized methods of architecture through presenting sustainable alternatives to current building techniques, while also promoting a crucial need to shift in material choices and design approach by starting at the community/local level. This work aims to become a point of reference and example for students and architects across disciplines, as well as promoting the voices of indigeneity and researchers who identify as BIPOC designers, like myself. This is also intended to help document the narratives of local communities and to provide a voice to those who often go unheard like indigenous communities of Madagascar.

GOALS:
1 - Put hemp/hemp-clay in the picture, contributing to knowledge development of the material and its application in the local context and industry.
2 - Innovate the material's potential, like combining hemp and clay
3 - Highlight the benefits of hemp/hemp-clay both socially and ecologically.
4 - Promote natural materials and traditional methodology for sustainable resource use within construction.
**METHODOLOGY**

This thesis is developed through background and theoretical research, personal experience, experimentations, and design(s). Through material experimentation, this thesis aims to contribute to the knowledge of hemp-clay technique in eco-construction and assess its potential with building design. As a first step in the process, attending hands-on workshops and background research (literary sources and interviews), gave the context of the complexities in how hemp is cultivated, defined, and currently applied. The work has a strong focus on theoretical research and preliminary experimentation studies, which has been an important process all along the work. Some architectural case studies were referenced that pertained to vernacular architecture and in-situ like 3-D printing clay. A variety of organizations (from hemp producers to designers) have been interviewed formally and informally including hemp farmers, designers/artists across disciplines, researchers, architects and professionals working with hemp in construction. Gaining their knowledge and perspective was valuable in contributing to the ever growing field of hemp research, especially hands on experience.

Material exploration of hemp-clay was done through experimentation, however due to time and access limitations, additional performance tests were not able to be performed. Several samples were made with different proportions, shapes, and density. The experimentations led to a bio-inspired design, or biomimicry, by local and indigenous communities; helping demonstrate the possibilities of working and integrating hemp into already existing systems found in nature and human culture. As discussed prior, Madagascar is well known for its enriched clay soil, and even in traditional Malagasy belief the clay-soil is red as it is symbolic of human flesh, reestablishing our regenerative connection and veneration to the land.
PROPERTIES OF CLAY
Clay represents a unity of the earth. To quote researcher Commere (2022):
“Clay provides the cohesion of the soil, acting as a natural binder. Cohesive soils, also called “rich” or “clayey”,
are best suited as binder for natural fiber aggregates (Gaia Architects, 2003). It is preferred to have above 30% of clay by volume. If suitable clay is available on the site of the project, the excavated soil for the foundations can be directly reimplemented in the building.” (Commere & Högskola 2022, 65).

When using clay it is important what type of clay and its make up, as it can determine the shrinking and swelling ratio (Commere 2022, as cited in Minke 2012). Gathering inspiration from Commere’s sample testing with hemp-clay, who referenced Gaia Architects, I discovered adding fibers like hemp into clay can prevent the shrinking while also aiding in water absorption and fortifying the form of the hemp-clay (Commere 2022).

MATERIAL EXPERIMENTATIONS
To conduct this masters thesis, hands-on material experimentation was carried out as a tool of discovery to better understand the material, and to test clay and shiv ratios. I referred to my past experiences and cultural practices with clay, to help with the investigation and creating samples of hemp-clay. From where knowledge is social, the clay technique was transferred throughout our childhood by my community on how to form and shape with clay through participatory design. I worked in small batches to create hemp-clay, in which the clay was obtained from the RISD 3-D store. The tested shiv: clay volume ratios can be located within the index page for reference.

Exploring the versatility of the material (hemp) was very important when conducting the experimentations. Three forms of the plant were used such as the hurd, the fiber and the powder. A building material (component) is produced from each one of these forms.
VERSATILE MATERIAL

VARIOUS FORMS INVESTIGATED

VERSATILE MATERIAL

FIBER POWDER

MICROSTRUCTURE

HURD

FIBER

POWDER

SAMPLES

BRICK

FACADE & ACCOUSTIC PANEL

LIGHTWEIGHT BUILDING BLOCK
OBSERVATIONS
My research has revealed that there are a number of ways in which indigenous knowledge can be incorporated into biomaterials research, including the use of traditional materials and techniques, and the involvement of community members in the research process. Biomaterials can also be used to preserve and promote indigenous knowledge, for example by creating with the community that incorporates traditional beliefs, ideas, motifs, and/or designs from the natural community.

THE CLAY MATERIAL
A test on binding with hemp-clay was conducted and recorded. An index with the results has been included at the end of this thesis. The hemp-clay demonstrated that fibers could create not only flexible and load bearing forms but could also reduce the ratio of shrinkage.
Inspired from the porosity of the material (hemp hurd) observed in the SEM (scanning electron microscope), a hexagonal block has been extracted and used as a base. A set of various pieces is then derived from it (photo of full set could be found in the index page). The hexagonal geometry is especially a reflection of the strategy that bees have adopted which is "less wax, more honey". Also, it is the most stable (form) mechanically using less material.
BASE MODULE
ADAPTATION TO LOCAL CONTEXT

Accessibility is a major point that needs to be addressed when it comes to countries like Madagascar, especially when it’s related to advanced technology. A question has then raised: how to democratize the knowledge/technique and make it accessible? As part of the answer, each module has been adapted to work with the local context/knowledge adopting the idea of open source. A first attempt with the base module has been produced and a drawing/instruction manual on how to use the slip casting would be produced.
DESIGN APPLICATION
PAST, PRESENT AND FUTURE

WALL SYSTEM
COMPATIBILITY & ADAPTATION

LOCAL & CURRENT CONTEXT

PAST & PRESENT
FUTURE

Exploring the potential application of the material by designing building materials extracted from the fiberous and powdered forms of the plant. Acoustic/facade panels are then developed. Also, lightweight building blocks have been made leveraging the 3D printing technique (recognized as one of the future for in construction).
FUNCTION OF THE MODULES: NATURAL VENTILATION THROUGH THE HOLLOW PARTS OF THE MODULES.
In conclusion, my research has demonstrated the potential of biomaterials to safeguard and promote multigenerational knowledge of local communities in Madagascar, and the importance of incorporating indigenous science into biomaterials research. However, it is also important to recognize the ethical and cultural considerations that need to be taken into account when working with indigenous communities on biomaterials research.

In the age of petroculture we must find more sustainable building materials and construction methods to change their detrimental impacts on the environment and human health. This thesis work has focused on hemp and hemp-clay, promoting its benefits and bringing a more holistic understanding of the material. Even though this material is not new, like European countries especially France, its integration and acknowledgement has been by far the lowest in the U.S. (Kolodinsky, J. and Lacasse, H. 2021). I have thoroughly enjoyed researching this plant that, for me, was previously a taboo material and only knew it for its medicinal properties. Being able to deconstruct hemp on a microscopic/molecular level to a macro scale and finding its biological and beneficial characteristics it has to offer to both local Malagasy and ecological communities while also contributing to sustainability efforts. More personal investigations and observations were made by adding clay to hemp, allowing an expansion to scientific research and combination of vernacular architecture and form finding of clay through material experimentations.

Although this work has unearthed many advantages, it also brought to the forefront the constant constraints and challenges hemp continues to endure. The most well known challenge is the stereotype of hemp as cannabis, a recreational product from the mid to late 50’s, misdirecting its many benefits like easy cultivation and durable fabrication. Hemp-clay technique is an alternative and innovative solution that can be applied at a local and global scale, however, its support is currently small resulting in a slow beginning process of research, development, and testing. I have personally witnessed the research gap in hemp-clay on a larger scale which leads to the biggest hurdle hemp-clay will face - how to develop it in the public sectors and urban context to be recognized as safe, durable, and cost effective. Much of the research to support these findings are more widely available in Europe but restricted in the U.S. Earthen materials like clay and hemp, are common materials in traditional architecture and seen across cultures over time. However the materials now are being labeled as new and unknown due to the lack of recognition and research, creating a difficult segway in the large scale
Sector, especially with the U.S. Coming back to the local context of Madagascar, it requires a great deal of time and sensitivity to reintroduce this topic to local Malagasy as it has not only been considered taboo but symbolic of colonialism and Westernization. It also raises concerns of an external force or country taking over and monopolizing the resource/method (hemp-clay) as observed prior with colonization in Madagascar and its long-term battle with extraction of resources and biopiracy (Reid 2009).

The followed methodology has allowed me to conduct more in-depth research on the important aspects of hemp/hemp-clay, looking into raw resources, working methods, performances, and climate impact. This thesis allowed me to work on a personal level, which architects rarely get the chance to do as well as an opportunity to combine and interconnect my cultural identity to vernacular architecture, biology, anthropology and scientific research. The process was very gratifying, a new way of researching and discovery to be interactive with architecture through the realms of creativity, innovation, and analytical of the development of biomaterials.
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INDEX
HISTORICAL USE OF HEMP

Origins of Use
The common hemp plant, Cannabis Sativa, is one of the earliest recorded domestically grown plants, with evidence of its cultivation since the Neolithic times. It is thought that the plant originated in China.

Spread
Cultivation gradually spread westwards through India and into the Middle East, Africa, and the Mediterranean, where hemp formed an essential part of the livelihood and culture of the people who grew it. Apocynum cannabinum, indigenous to North America, was used for textiles, food, and medicine.

Use in Europe
It is believed that hemp made its way to Europe in approximately 1200 BC. During the middle ages, hemp became an important crop, contributing to economic and social development by supplying much of the world’s need for food and fiber.

Use in America
Hemp might have been cultivated in America before the Europeans arrived. When the Puritans arrived, hemp had reached the continent. California, Kentucky, New York, New England, Virginia, Massachusetts, Louisiana, and Missouri were some of the many states where hemp was grown.

Neolithic Times
(12,000-6,500 BC)
- Hemp has been found in ancient pottery
- The word Canvas derives from cannabis - a fabric made from Hemp, valued for its durability
- The Sumerians incorporated it into their medical treatments

2700 BC
- The Chinese used it to make clothes, shoes, ropes, and an early form of paper
- Egyptian and Greek records reveal the importance of the hemp plant to the lifestyle and economy of these civilizations

1200 BC
- Kings of England promoted the cultivation of hemp for everyday uses such as linen and rope, and it contributed to their supremacy in military sailcloth and rigging

1545
- Henry VIII passed a law making it compulsory for farmers to grow hemp (1509-1547)

SOURCE: HEMPLIME BOOKLET, PARSONS HEALTHY MATERIALS LAB
BENEFITS & USAGE

Flowers + Seeds
- Psychoactive
- Plant generally

Seed
- Protein Source
- Fuel
- Lubricants
- Ink

Hurd
- Mulch
- Chemical Ads
- Fiberboard
- Insulation

Fiber
- Netting
- Canvas
- Carpet
- Bio-composites
- Cloths

Stalk
- Bio-diesel
- Paper Products
- Cardboard
- Filters

Epidermis

Hollow Space

SOURCE: HEMPLIME BOOKLET, PARSONS HEALTHY MATERIALS LAB
World Oil Demand

The use of hemp and lime in the building industry can impact different sectors where oil is used. If hemp-based products replace petrochemical products, emissions created by areas like power generation, buildings, heavy-duty vehicle or petrochemicals would be reduced significantly.

Petrochemically based vs hemp based products

A comparison between the environmental impacts of petroleum and hemp based construction products. Petroleum based products have multiple negative environmental impacts while comparable hemp based products reduce energy consumption and sequester carbon dioxide.

<table>
<thead>
<tr>
<th>Petrochemically Based</th>
<th>Hemp Based</th>
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<tbody>
<tr>
<td>40% of greenhouse gases are produced by the building industry</td>
<td>110 kg of CO2 are sequestered in one cubic meter of hempcrete</td>
</tr>
<tr>
<td>7.6 million barrels of oil are used to heat homes per day in the United States</td>
<td>50-80% energy conservation for heating + cooling hemp structures</td>
</tr>
<tr>
<td>1.5 million barrels per day are used by the construction industry</td>
<td>One hectare of industrial hemp can absorb 22 tonnes of CO2</td>
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<tr>
<td>16% of pesticides and 7% of insecticides are used by conventional cotton</td>
<td>0 fertilizers or insecticides are required by hemp.</td>
</tr>
<tr>
<td>170 Million tons of building related waste were generated in 2003.</td>
<td>0% on-site waste</td>
</tr>
<tr>
<td>233% More frequent smile signatures caused by synthetic furniture and construction materials</td>
<td>100% non-combustible with a 2-hour fire rating</td>
</tr>
</tbody>
</table>

Diagram 1.1 Global Oil Demand and Environmental Impact

*Sources: Reference Section
PROCESS PHOTOS

Production of a hemp clay brick using a mold based on 1 to 1 scale/dimensions of standard brick. The photos above illustrate the steps from mixing to drying.

Hemp fiber with clay is used to test a fiber reinforced panels. Two techniques are used for the exploration: the sandwich where the fiber is placed between two layers of clay and pressed between two molds, the other one is using paper mache where the hemp fiber with clay is applied to the mold (middle picture) and removed when dried enough.

Experimentation with hemp powder and clay. The process is mostly relying on 3D printing. The photos are illustrating the process from mixing (far left), preparing/loading the clay the set-up (a personal desktop ceramic 3D printer, 2 mini-fans) to printing one of the modules (far right).
### KILN SETTINGS

<table>
<thead>
<tr>
<th>DATE</th>
<th>SETTINGS</th>
<th>4/19/2023</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LONG FIRE – 14hours</td>
<td></td>
</tr>
<tr>
<td>60°C</td>
<td>200°C</td>
<td></td>
</tr>
<tr>
<td>200°C</td>
<td>1000°C</td>
<td></td>
</tr>
<tr>
<td>150°C</td>
<td>1100°C</td>
<td></td>
</tr>
<tr>
<td>150°C</td>
<td>1575°C</td>
<td></td>
</tr>
<tr>
<td>150°C</td>
<td>1880°C</td>
<td></td>
</tr>
</tbody>
</table>

**OBSERVATION**

| 525°C | Strong burnt smell, firing had to be interrupted (see attached picture), pieces turn black |

<table>
<thead>
<tr>
<th>DATE</th>
<th>SETTINGS</th>
<th>4/20/2023</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SHORTER FIRE – 10H 40MINS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STARTING TIME</td>
<td>8:45 AM</td>
</tr>
<tr>
<td>60°C</td>
<td>200°C</td>
<td>HOLD FOR 30 mins</td>
</tr>
<tr>
<td>200°C</td>
<td>1000°C</td>
<td>NO HOLD</td>
</tr>
<tr>
<td>150°C</td>
<td>1100°C</td>
<td>NO HOLD</td>
</tr>
<tr>
<td>250°C</td>
<td>1820°C</td>
<td>NO HOLD</td>
</tr>
<tr>
<td>150°C</td>
<td>1880°C</td>
<td>NO HOLD</td>
</tr>
<tr>
<td>MAX</td>
<td>1900°C</td>
<td></td>
</tr>
</tbody>
</table>
SAMPLES PRODUCED
PRODUCTION OF SAMPLES WITH VARIOUS RATIO

PROTOCOL TEST SAMPLES

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Proportions</th>
<th>Consistency</th>
<th>Wet Weight</th>
<th>Dry Weight</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1 vol Clay + 1 vol hemp-lime</td>
<td>Creamy</td>
<td>134g</td>
<td>99g</td>
<td>27%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>144g</td>
<td>103g</td>
<td>28%</td>
</tr>
<tr>
<td>S2</td>
<td>1 vol clay + 2 vol hemp-lime</td>
<td>Creamy</td>
<td>124g</td>
<td>87g</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>135g</td>
<td>97g</td>
<td>28%</td>
</tr>
<tr>
<td>S3</td>
<td>1 vol clay + 3 vol hemp-lime</td>
<td>Creamy</td>
<td>112g</td>
<td>67g</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>112g</td>
<td>80g</td>
<td>29%</td>
</tr>
</tbody>
</table>

Weight/Shrinkage Avg

<table>
<thead>
<tr>
<th>HEMP - CLAY + LIME</th>
<th>HEMP - CLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>32%</td>
<td>28%</td>
</tr>
</tbody>
</table>
MODELS

MODULES/SET

ROW 1: LEFT TO RIGHT
- CORNER PIECE, CORNER PIECE 2, INFILL PIECE

ROW 2: LEFT TO RIGHT
- BASE MODULE, INFILL PIECE, CORNER PIECE 3
PHOTOS OF MODELS

ROW 1: LEFT TO RIGHT
- PANELS, SCREEN WALL SYSTEM, STRUCTURAL WALL

ROW 2: LEFT TO RIGHT
- HEMP CLAY BRICK IMPLEMENTED TO LOCAL CONSTRUCTION TECHNIQUE, HEMP CLAY WALL, INITIAL ITERATIONS OF THE 3D PRINTED MODULES.