Rice Hull Material Synthesis:

TRANSFORMING WASTE INTO CIRCULAR DESIGN

LIAM MCARDLE-HANKIN-
liambmh@gmail.com
December, 2022

PROBLEM STATEMENT
project overview

THE PROBLEM
As capitalistic progress pushes our societies forward the need for raw materials continues to grow and becomes more important. However due to a lack of available resources and an all time high of waste pollution finding its way into our ecosystems, designers and consumers alike have to rethink the way we consume and handle waste. The immense amount of ocean waste has formed five giant garbage patches, the largest — the Great Pacific Garbage Patch — includes an estimated 1.8 trillion pieces of trash and covers an area twice the size of Texas. One study showed that synthetic microfibers make up as much as 85 percent of all beach trash. Much of the materials we use in our products increase our pollution and climate harm such as extracting petroleum and lumber.

THE SOLUTION
Adopting circular design practices. Circular design (circularity) entails that the life cycle of a product follows a circular path and not a linear one. Many of our day to day products follow a linear path that begin with the extraction of raw material then the manufacturing of product followed by the disposition leading harmful waste pollution. Think about where you're possessions will go once the are no longer usable. Currently only 8.6% of the world economy is circular, a staggering low number. Circlular designed products follow extraction of raw materials, manufacturing of the product, then instead of being disposed of, the product can either be repairable, reused for parts, recycled for material, or are biodegradable. Meaning the cycle loops with the production of the product while drastically reducing raw material consumption and waste output.

CASE STUDY
The waste to raw materials, and a circular design

BENEFICIARIES
Due to the nature of circularity both manufacturer and consumer are benefited. For starters producing less pollution and waste benefit all of us, and directly boost a manufactures company culture, and can grant tax benefits for producing less carbon and waste. Furthermore once a circular system is in place a manufacturer can benefit from returning customers, an internal waste to raw material source, and morally. Furthermore utilizing waste to produce your raw material can benefit both parties.

LOCATION
This Project will be taking place in Northern California, primarily San Francisco and Sacramento county. The material source has been specifically chosen do to its close geographic location to the place of production. This limits carbon output, and is one of the many tactics that can be used to increase circularity and sustainability.

project overview

SIGNIFICANCE

Quantify the problem (show it's significance by number effected or other measures of pervasiveness)

Begin with your anecdotal observations and conclude by referencing or siting one to two external sources.

Leading up to this project I took many beach and river walks and noted the amount of litter and trash I saw washing upon shore. Moments like this inspired me as a product designer to try my best to contribute to sustainable practices and hope that my products don't end up floating in the ocean for eternity. Five hundred billion tons of resources were consumed globally over the past six years. The want for more as a society has forced us into a corner and we need to start rethinking how we consume.

COSTS

200ibs Rice Hull— $0

Gas — $55

Chemicals — $80

Manufacturing — $62

Additional materials — $20

BENEFITS

As capitalistic pressures continue to devastate out natural world and create climate chaos it is up to designers and makers to rethink how we produce consumer goods. Adopting circular design ensures the most sustainable routes are followed and tries to minimize a products waste and carbon footprint. Finding ways to reduce waste and rethink our raw materials benefits companies and consumer alike.

SUMMARY

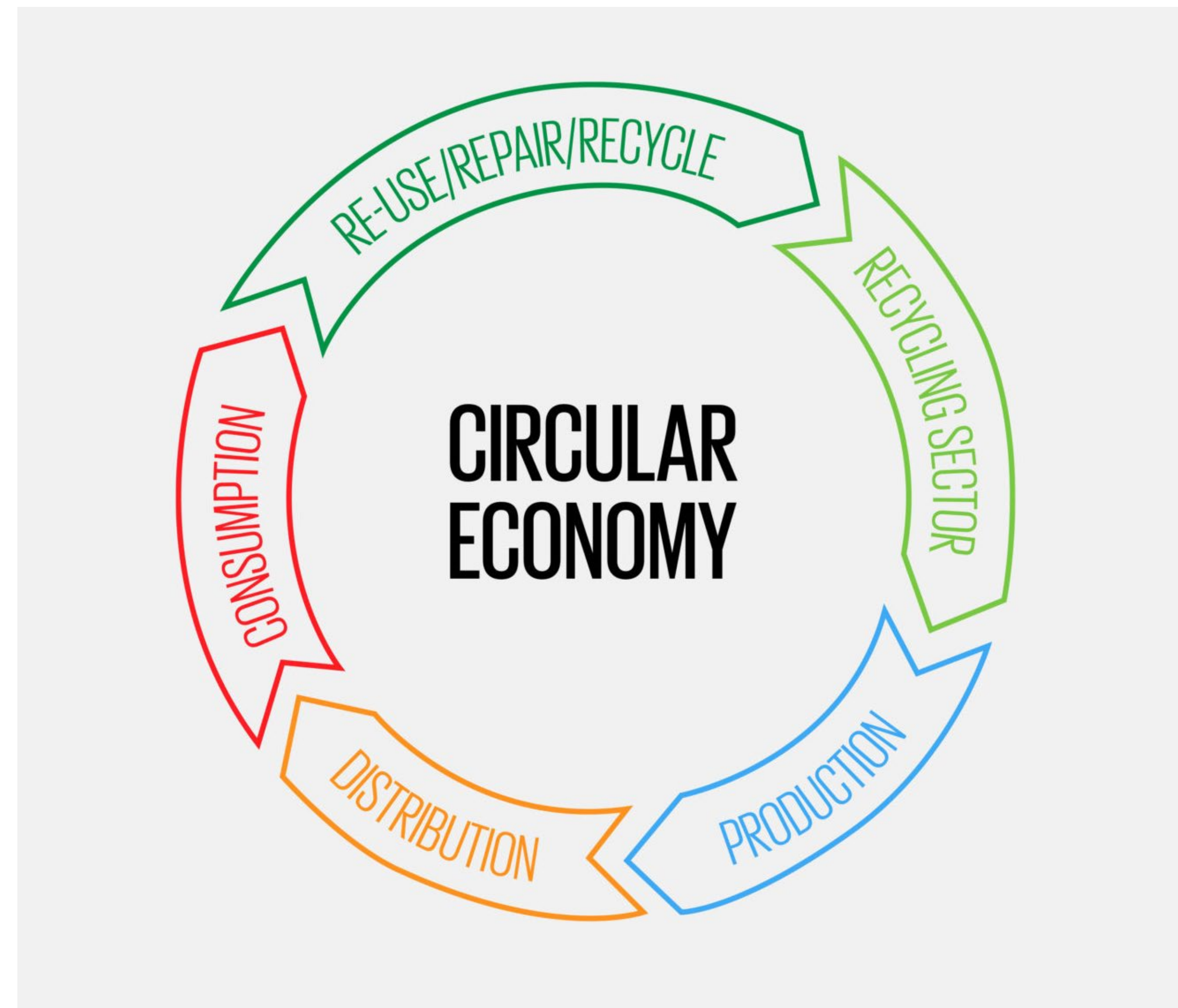
The speed of "progress" and human behavior have lead to over-consumption, drastically harming our environment and leading to a scarcity of resources. As a product designer I fear becoming apart of the problem and therefore adopted design circularity for this roject to showcases its potential, and importance. Furthermore transforming waste material into products will take this project to the next level of circularity by limiting the need for raw material extraction.

DELIVERABLES

A CASE STUDY ON CIRCULARITY

The materials in which products are made of can greatly dictate its life cycle and substitutability. For instance a single-use plastics like polyethylene are derived from fossil fuels leaving big carbon foot prints, and they are not recyclable leading to ocean waste. **4.8 and 12.7 million tonnes of plastic pieces are dumped into our oceans yearly.**

Therefor in order to achieve maximum circularity the materials used for this case study are not only biodegradable and/or recyclable they are made from waste materials local to my very own Sacramento region. Furthermore the deleveriable will include indepth researching into transforming waste into raw material, in this case rice hulls, that will be used for a chair design.



WASTE TO RAW MATERIAL
finding the right choice

Finding the proper waste material was challenging as it had to be accessible, local and manageable in order to reduce carbon and work within a student budget. I searched for helped within SFSU and found a senior level course on environmental waste management and meet with the instructor, Professor Blencha.

She was not only excited about a student taking on a circular design project but was helpful in brainstorming waste materials that would work for my project. Amongst the ideas bounced around such as ocean litter, and spent brewers yeast, the one I settled on was rice hulls.

90% of California's rice comes from the Sacramento county. After production many farms had been burning a portion of their rice hulls with no further purpose other than to get rid of them leading to unnecessary carbon emissions, and in my case a waste of potential.

Rice Fields of Frontier AG in Davis, CA

RICE HULLS
What are they

Rice hulls or husks are the non-edible outer most protective layer surrounding each individual grain of rice. Not to be confused with the bran which is another coating one layer deeper that can be found on brown rice. Rice Hulls are comprised of mostly non-starch carbohydrates and have high contents of lignins, and silica. Roughly every 100kg of rice produces 20kg rice hulls. **Although rice hulls are used for a variety of things such as live stock feed, alcohol brewing, and fertilization there is so much that it is still largely a waste byproduct. In 2021 the united states produced 9.74 billion kg of rice.**

Therefore the potential to use rice hulls as a replacement for other non-substitutable materials like plastics, hardwoods, and cement was considerable.

RESEARCH
Sourcing and interview

SOURCING

After contacting numerous amounts of Rice farms I finally got in contact with John Pereira from Frontier AG, an agriculture company of rice farmers and experts. John supported this project by donating 200lbs of rice hulls!

Frontieer AG in Davis, CA

JOHN PEREIRA FROM FRONTIER AG

Q:Where do your rice hulls go currently?

A: Well a lot goes to the poultry industry for bedding for chickens. Other for cleaning...Makes surprisingly good cleaning material for blasting off debris on air planes. Theres load's of ways to use rice hulls could be used, however only a small percentage is due to how much is produced.

Q: When did you start realizing the potential of rice hulls?

A: Only in the last decade or so have they become more prevalent. We ourselves found a way to compress and package them because we saw the potential they had in numerous fields.

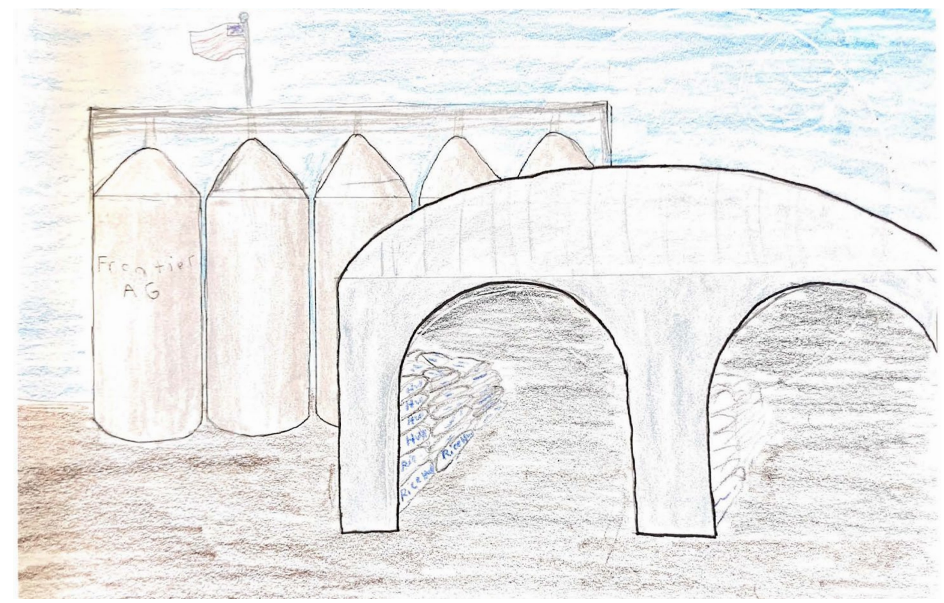
Q: How do you feel or think after hearing about this project?

A: I think its great! Like I said there is alot of potential with rice hulls. I look forward to seeing the outcome of your project and happy we were able to help.

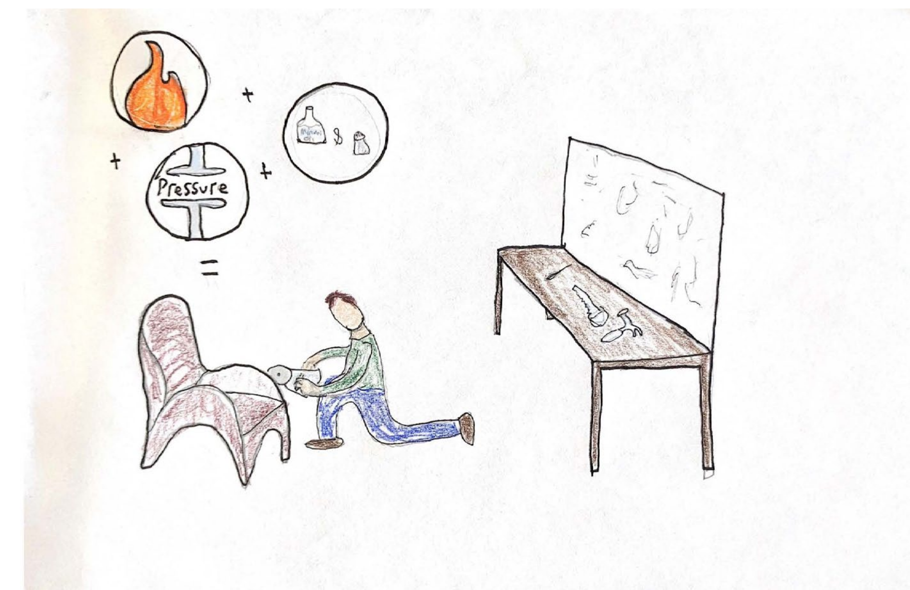
Frontier AG in Davis, CA. and Warehouse with rice hull packaging.

STORY BOARD
user scenario

1.



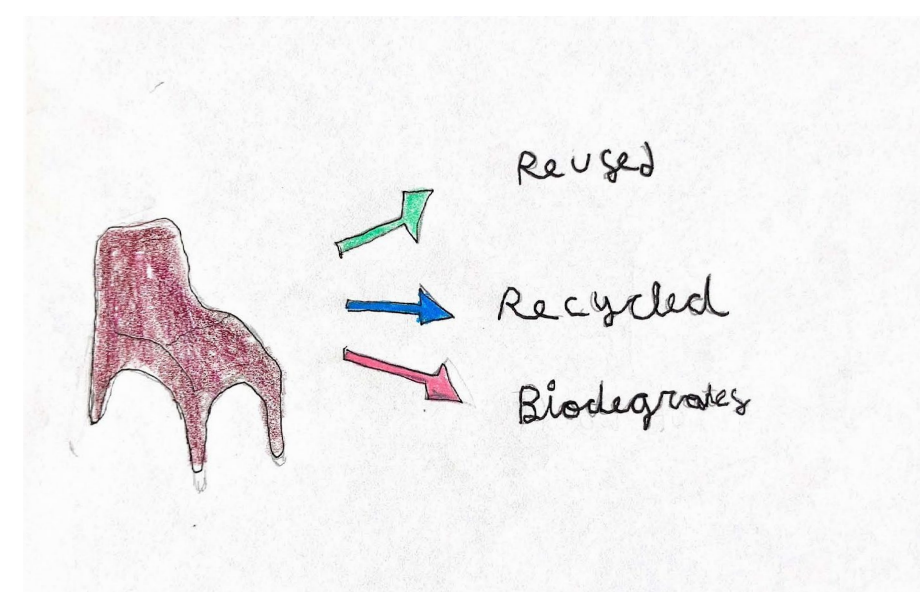
2.



3.

4.

5.



6.

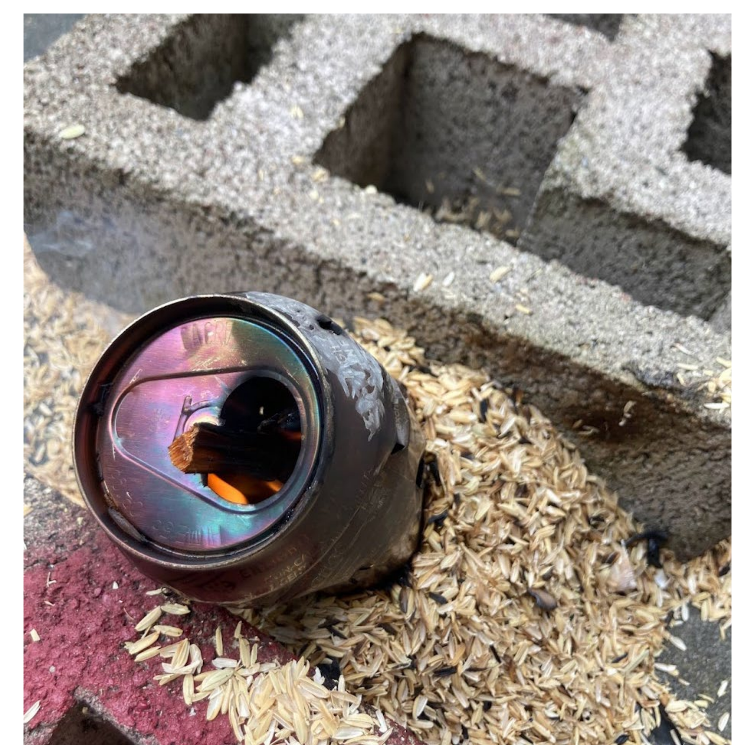
Material Research and Experiments

MAKING RAW MATERIAL

9

MATERIAL EXPERIMENTATION

Rice Hull Preparation



INITIAL PREPARATION

Before I began experimenting I altered the form of the rice hulls in numerous ways such as boiling for long periods of time, baking, chopping, grinding, and burning them to later use in different sample experiments..

GOAL

Using rice hulls to replace lumber, helping combat deforestation and producing less green house gases. Trees sequester carbon and release when they are cut and dried. Although it varies by tree, wood is roughly 50% carbon by dried weight. Furthermore trees require a greater amount of resources to produce such as water, time and space leading to detrimental effects on ecosystems and bio diversity.

Therefore one of the three main focuses of raw material I choose to synthesis was a rice hull composite lumber.

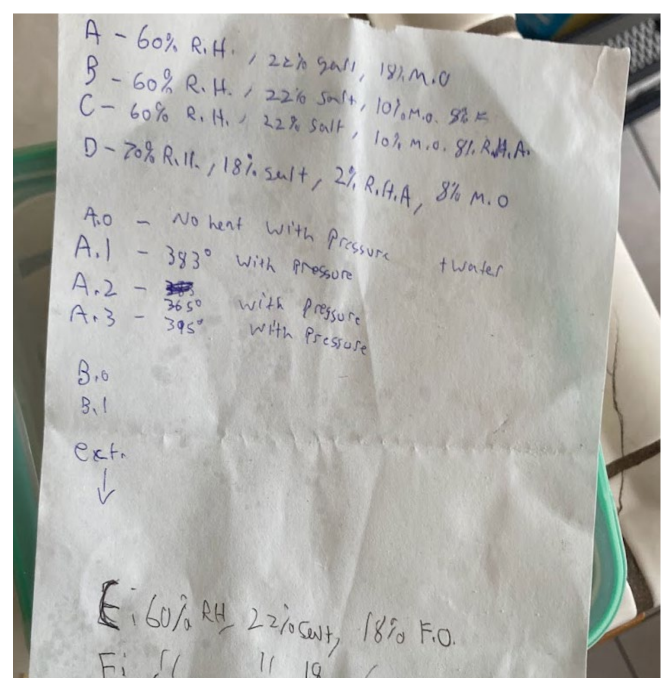
INITIAL TESTING

For the initial testing I had a lack of resources and went with a more rogue approach loosely following my primary research. I filled cut aluminum cans with different mixtures of ingredients hoping to produce a material in the right direction.

Variables

- -Mixture (Rice Hulls, Miner Oil, Flax Oil, Salt)
- -Heat
- Pressure

The result of this experiment was mainly inconclusive as the various mixtures failed equally. I found that in order to make composite board I needed immense pressure, and heat.



RICE HULL LUMBER
sourcing

PRESSING FORWARD

After failing many times trying to produce a lumber replacement with a rogue technique and getting an understanding for the precision and research it would take to solve the material I went back to the drawing board. Through which I found that by utilizing a bio-polymer as a binding agent I could get better results. Due to a lack of and heat presses available on campus I resorted to reaching out to a friend of mine nice enough to loan me his heat press which he would use to make cannabis resin.

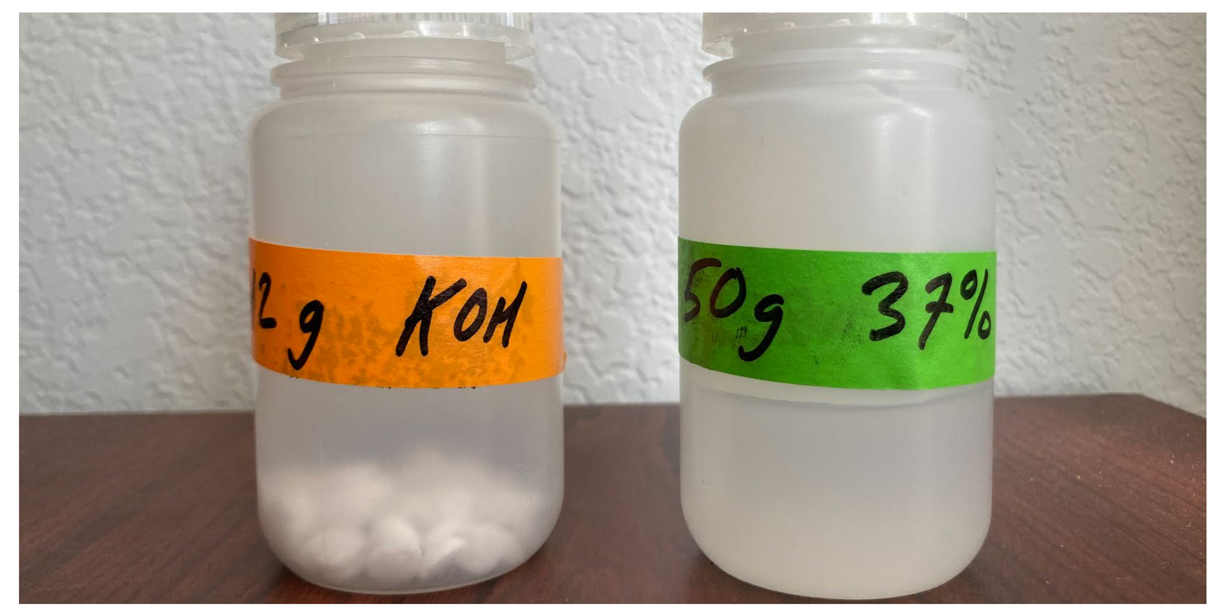
CASEIN

Casein, otherwise known as paracasein, is a bio-polymer derived from milk protein. I decided that utilizing casein as a binding agent was one of the best options due to its non-toxic biodegradability. Furthermore California is one of the highest milk producing states and **San Joaquin Valley,** only an hour away from both Sacramento and San Francisco, **produces 90% of California's milk so it fits the bill with locality.** Lastly 17 billion pounds of milk is wasted each year in the US. **The beauty of casein is that it can be derived from expired milk**, meaning we can continue to use waste to our benefit rather than extracting raw material.

LAB HOOK UP

In order for Casein to open up its polymer links it needs an high alkaline in which it can then inter mingle those links with that of what you bind it to, in my case rice hull fibers. After the links intermingle you need an acid to curdle the proteins which reform the links into strong bonds.

After reaching out to the chemistry department through emails and drop-ins I got an unofficial meeting with the department head, Bruce Manning. Bruce was intrigued by my research findings and donated a hand picked portion of Hydrochloric Acid (HCl) an alkaline and Potassium Hydroxide (KOH) for a high acidic solution.



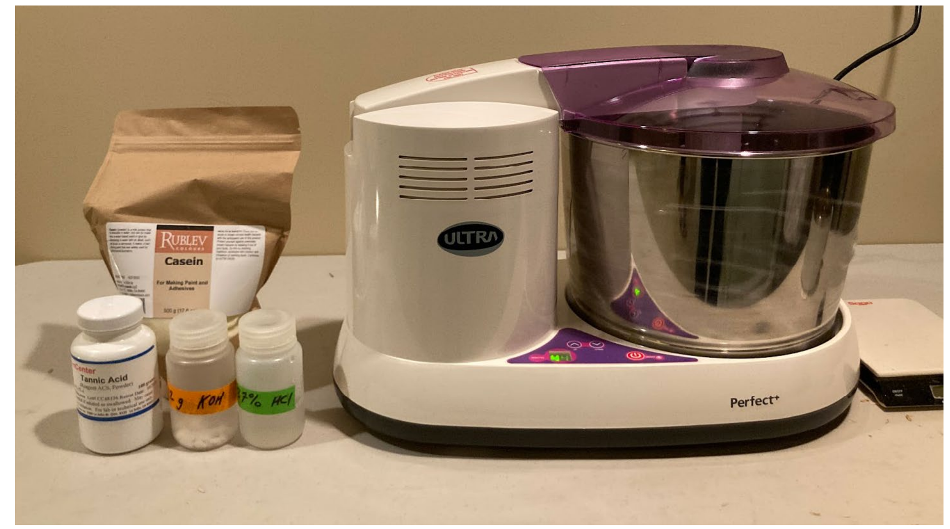
THE GOOD THE BAD AND THE UGLY

After learning more about the chemistry of what I was trying to achieve and with the help of a heat press I was able to head in the right direction testing a samples with a variety of ingredient mixtures and tactics that taught along the way through trial and error.

RICE HULL LUMBER
material experimentation

LINKING THE BIOPOLYMERS TO THE RICE HULL FIBERS

As stated I needed to find a better way to link the Rice Hull fibers with the casein (Originally I was aiming for a more plastic type material, however the result ended up forming a solid lumber replacement.). This tactic proved to yield the best results based of strength and similarity to lumber or particle board.



Wet grinder used to help homogenizes mixture.
Ingredients: 60g Rice Hulls, 60g Casein, 6g KOH, 6g HCl, 8g Tannic acid


Grinding Rice Hulls and ingredients through about 3 stages. Time 6 hours.



The lighter color of the mixture on the right comes from adding the acid (HCl), and gets lighter due to the milk proteins curdling. Adding the acid seconds as a preservative.


Straining the solids.


Letting the solid, bread crumb like substance dry before pressing at 2600F

Pressing Particle board

RICE HULL LUMBER
material final

RICE HULL PLASTIC
initial research

PLASTIC PROBLEMS
It is no secret that plastics formed from fossil fuels have a massive carbon footprint, are hard to recycle if even possible at all, and usually lead to waste. **28 billion pounds of waste makes it into our oceans every year.** From ciggerate butts, to dippers, to takeout food containers, single use plastic waste is abundant within our society, ecosystems, and even within our bodies.

GOAL
To synthesis a substitutable, biodegradable, and non-toxic bio plastic that could replace harmful plastics derived from fossil fuels, and overall work within a circular product design.

Stock Image by: Unknown

APPROACH

For the bio-plastics I experimented with multiple types of binding strategies utilizing casein, glycerin and starch, and pressure from the heat press. Although casein is a viable bonding agent that works within this projects design circularity constraint I wanted to test more ways to synthesis bio-plastic.

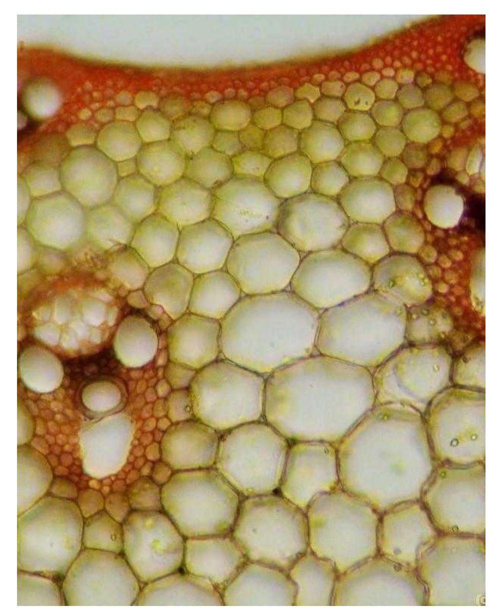
STARCH

Many resources explained how to successfully synthesis bio-plastic using a homogenized mixture of starch, glycerin, and vinegar. For the sake of time and a lack of resources I used potato starch to make similar material samples of bio plastic. However before going down this route I wanted to make sure this technique could be possible using a majority of by product from the rice industry.

Although rice hulls are a non-starch carbohydrate, rice shoots and leaves, another byproduct from rice farming, contain starch! Faculty of Agriculture, from Tohoku University Japan, Kanoe Sato writes in his article

“The rice plant is a conspicuous cereal which accumulates many starch granules in its tissues”

He goes on to explain how throughout rice cultivation starch granules move within the plant. After harvest of the grain, about 20% of those granules are left within the plant internodes. Meaning in theory the rice shoots, a waste material could be used for its starch contents to create bio-plastics!



Microscopic Rice stem / Rice Stem Internodes.

Photos by: Bangabandhu Sheikh Mujibur Rahman Agricultural University

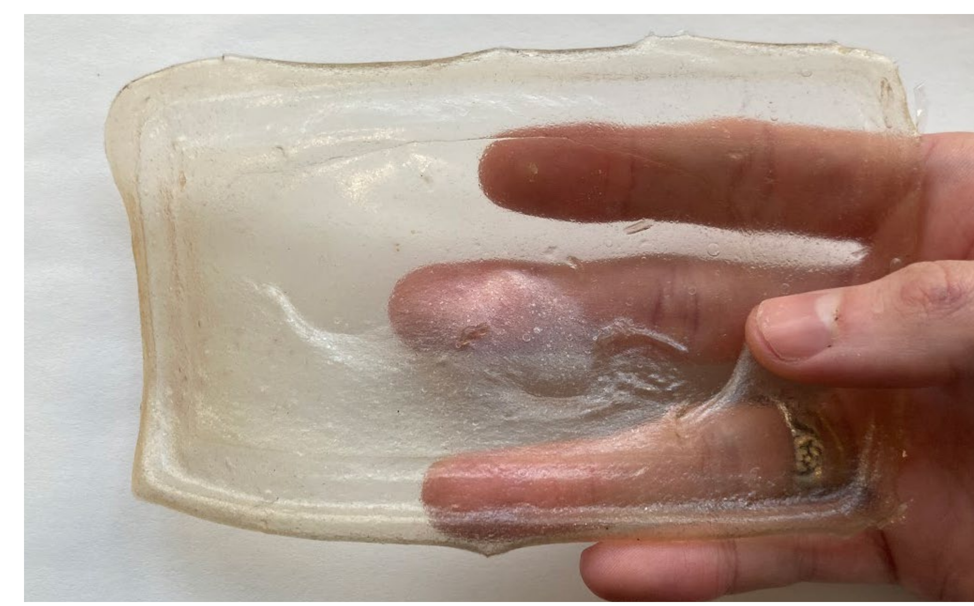
RICE HULL PLASTIC
material experimentation

STARCH, GLYCERIN, VINEGAR

This experiment was fairly straight forward as it was well documented through online resources.

First I added and mixed 4 tbsp water, 1 tbsp distilled water, 1 tsp glycerin, 1 tsp vinegar. Once mixed thoroughly add to stove at low heat (for best results heat mixture between 194-204 degrees F) and continue to mix until a gelatinous mixture forms and turns semi-transparent.

Spread on non stick surface (I first used aluminum foil which ended up sticking and ripping the plastic) and let dry up to a week (to avoid cracking do not place in direct sunlight).



Final product

EDUCATED GUESS

After following a resource to make a casein and hemp bio-plastic but instead synthesizing rice hull particle board (pg.14) I decided to try another crack at a bio plastic with a recipe of my own based of my research and previous experiment findings.

Up to this point I had learned a great deal about how and why certain chemical agents were used in conjunction with other materials to either break them down or form bonds. For instance casein dissolves in high alkaline solutions, tannic acid helps create water insolubility, and how glycerin acts as a plasticizer. Using this knowledge I experimented rogue once more.

SYNTHESIS

First in hastily threw in this sequence of ingredients into a beaker over low heat while stirring: Distilled Water, Sodium Hydroxide (NaOH), Casein, Chopped Rice Hulls, Tannic Acid, Glycerin, and Vinegar.

Poured in all the contents of the mixture on a baking sheet, and set them to dehydrate in the oven at 120 degrees F for 4 hours, and then continued to let it cure over night.

In previous attempts I had strained out the majority of liquid, letting them only air dry and the results were often too dry and crumbly. Therefore dehydrate them in hopes of retaining more bio-polymers seemed a viable option.

RICE HULL PLASTIC
Lemo plastic

RESULTS

The Bio-plastic I had formed was flexible, rubber like, and had a fascinating ugly look, I decided to nickname it Lemo plastic. Although pleased with the results, I knew I could do better.

Much of the contents were cured at different rates and were unequally distributed, mainly being that there were clumps of tannic acid within the material sample. Even though the sample had an interesting look however the functionality was jeopardized due to these errors..

2.0

For the second variation I used the same ingredients at slightly different quantities. Furthermore I mixed more refined rice hulls, casein, and tannic acid into a NaOH molar solution independently first before combining them. This allowed each ingredient to be broken down better ultimately leading to a much more homogenized mixture.

HARD PLASTIC

Taking a slice out of the lemo plastic and chopping it into small bits in a coffee grinder, I was able to wrap it in tin foil and pressed it at 280 degrees for 10 minuets. The result successfully produced a hard plastic made out of the same non-toxic biodegradable material.

RICE HULL PLASTIC
Lemo plastic

Lemo plastic 2.0

RICE HULL CONCRETE
initial research

CEMENT

As most are aware of, by far the most popular concrete blend in production, in use today and for hundreds of years, utilities cement as it binding agent. This industry **accounts for 8% of global CO2 emissions**. The Guardians Chris Michaels writes "if (the cement concrete industry) were a country it would be the world's worst culprit after the US and China." Cement is comprised up of limestone that has been fired at 1,500 degrees C which takes coal to do so accounting for 40% of its emissions. This reaction turns the limestone into calcium oxide or lime which releases the other 60% of emissions straight into the atmosphere.

Along with its devastating carbon dioxide output cement has other terrible traits. Cement is toxic leading to water and soil pollution, it also damages Earths most fertile layer called topsoil, it leads to land erosion and soil run off. Furthermore because of its toxicity cement particles can lead to respiratory disease and cancer. **Lastly cement requires immense water usage taking almost 10% of industrial water use.**

GOAL

To produce a bio-concrete alternative using rice hulls, a waste to raw material, as the primary component. This alternative is to be non-toxic, and work within circularity by either being recyclable, reusable, biodegradable or a combination of these aspects.

Photograph: Zoonar Alamy

Photograph: David Kook

RICE HULL CEMENT
initial experiment

HOW IRONIC

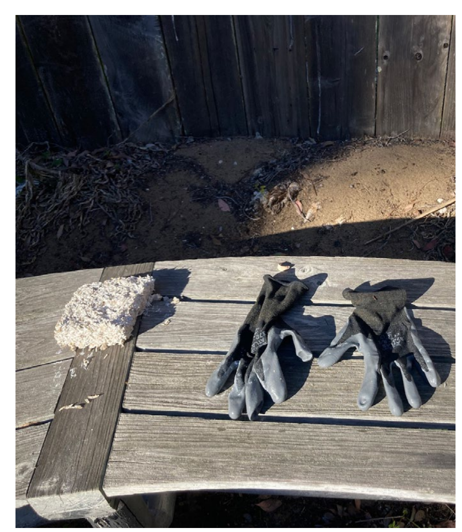
Eager to experiment I started without fully understanding why cement was terrible so my first experiments consisted of using rice hulls, chopped rice, and lime (yes lime, the material I just slammed on the previous page).

I mixed lime base binder, rice hulls, and chopped rice hulls at a standard cement ratio of 1:2:4 respectively along with some variations to test. Incorporating rice hulls as a gravel and chopped rice hulls as a sand.

RESULT

After learning more about terrible lime binders I completely abandoned this strategy. Furthermore the brick wasn't all that great anyway as it crumbled and dusted easily, disintegrated in water, and was toxic.

Concrete making station in backyard



Drying brick in sun

Rice Hull / Lime Binder Brick

RICE HULL CONCRETE
material experimentation

CONSISTENT FAILS

Once again I attempted to go with rogue experimenting, loosely following research and trying to craft my own version of a bio-concrete. The rogue tacits were failing as my bricks could not even support there own weight.

INTRODUCTION TO THE WONDERS OF GEOPOLYMERS

With a change of approach imperative I reach out to prodigious designer, and friend of mine, Kevin Rouff from Studio ThusThat. Kevin had worked on bio-concrete projects himself and introduced the concept of geopolymer binders. **Geopolymer binders can quickly form strong bonds with good mechanical properties and high compressive strength.** Geopolymer binders form when aluminosilicates, (minerals composed of aluminum, silicon, and oxygen, plus countercations) are homogenized with an activated alkaline solution.

RICE HULL ASH

When Rice hulls are incinerated it creates rice hull ash or RHA. Among aluminosilicates rice hull ash has one of the highest silica contents between 85-95%. RHA also is unique in because it is an organic aluminosilicates. Like other aluminosilicates, RHA has wondrous properties although we will be focusing on its geopolymer capabilities.

Important to note: Although farms burning an excess amount of rice hull waste produces pointless carbon emissions, RHA can be achieved substitutable. Through rice hull gasification energy can be harnessed, a far greener alternative to coal, and the by product would be RHA. **Meaning rice hulls could be used to generate energy, and the waste could be used to create geopolymer binders!**

In order to make RHA geopolymer binder I needed:

- Rice Hull Ash
- Sodium Hydroxide (NaOH)
- Sodium Silicate (Na2SiO3)
- Distilled Water

RICE HULL CONCRETE
gathering the ingredients

SODIUM HYDROXIDE / DISTILLED WATER
Both were easy to acquire and available for purchase at store fronts.

RICE HULL ASH
A much large quantity than that of what the aluminum can burn set up could offer. I ended up incinerating rice hulls multiple times each with a little more success.

Incinerating in the metal shop lab. This was a failure (don't let the OK signal fool you). The lab got uncomfortably smokey so the rice hull packages prepared had little ash content.

The packages in the fire got destroyed due so much of the rice hulls and RHA was lost to the flames.

Burning the rice hulls in a bucket directly over the flame yielded the best results with minimum lost of RHA, and a reduced amount of foreign particles.

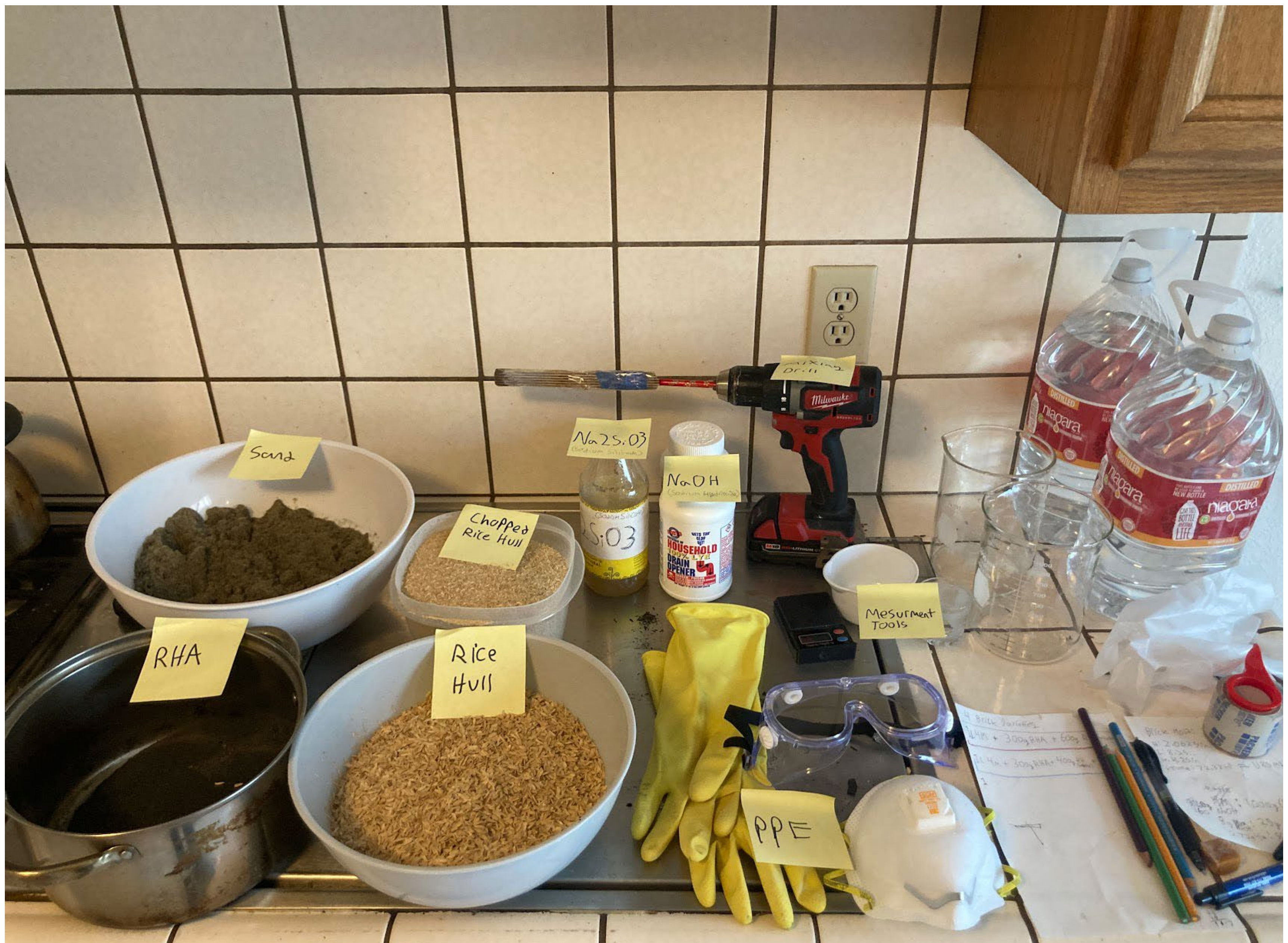
Successful rice hull ash yeild.

SODIUM SILICATE

Scouring the city for sodium silicate, also known as liquid glass, proved to be challenging. The best option was to order it online through Home Depot which took 5 days to receive.

Due to eagerness and time constraints sodium silicate had to be made myself. Mixing the appropriate amount of water, NaOH and silica beads forms sodium silicate. At the time the fastest way to get silica beads was to buy dried seaweed snacks and distribute them to whomever was in the lab, asking for only that "Do Not Eat" packet in return.

RICE HULL CONCRETE
material experimentation



MISE EN PLACE

All the needed tools, ingredients, PPE, and written formulas to start experimenting with RHA geopolymer binder and aggregates.

SUMMARY OF EXPERIMENT 1

A 4M NaOH solution with an 11:2 of Na2SiO3 (by volume) was mixed with 30% RHA (by weight). Mixing the slurry with a flat piece of wood on an electric drill until throughly mixed it was then used to produce four Rice hull brick prototypes.

The experiment went array by placing the brick molds onto a sheet with aluminum foil. Since learned, alkali solutions react with certain metals like aluminum producing hydrogen gas. No explosions occurred however the bricks suffered in strength and the results were tampered.

Furthermore it was realized that to much slurry was used in making the bricks, delaying cure time and results. The bond was also weakened due to a lack of sodium silicate. In short these brick were not successful.

RICE HULL CONCRETE
material experimentation

ANOTHER ATTEMPT

In the next attempt the molar solution was bumped up to 8M in order to create a stronger activated alkali solution. However up to this point there was still not enough sodium silicate present leading to a reverse effect making the bond weaker.

Furthermore a batch of RHA was used from the aluminum foil packages that had been burned in the fire. leaving behind tiny particles of aluminum which once again reacted forming gas, ultimately making these bloated looking bricks worse than the first attempt.

FINALLY, A BRICK

Learning from past attempts, a more prudent approach was taken using an appropriate an amount of ingredients. The results were a variety of RHA geopolymer bricks, some better than others, but the best having structural integrity and a unique appearance.

Raw Materials Derived from Rice Hulls.

RAW MATERIALS
conclusion

Trying to synthesis raw material from rice hulls, a waste material, proved to be extremely difficult, and the task was severally underestimated. Looking back I realize my attention to each form of rice hull material (composite lumber, plastic and concrete) was spread to thin. Taking time to focus on each material individually would have been better. That said the research and experiments of all synthesis types helped build around each other and formed an overall better understanding of the choosen waste material.

Furthermore taking risk and going rogue with experiments is best after learning as much as possible as it can either make or break you (most likely the former), yet it is recommended in moderation due to its exciting nature.

Lastly, although non of the synthesized rice hull materials are perfect, this project has proven that with research, diligence, and creativity waste can be utilized as a raw material, ultimately being rendered as design circularity.

CIRCULARITY CHAIR
Introduction

PROJECT BEGINNINGS

A desire to design and build a chair following design circularity was a goal roughly two months before ever learning of rice hull existence. In fact this drive lead to how the project ended. Only after realizing that the majority of time would have to be dedicated to solving for material synthesis did the goal of constructing a chair get pushed to the wayside.

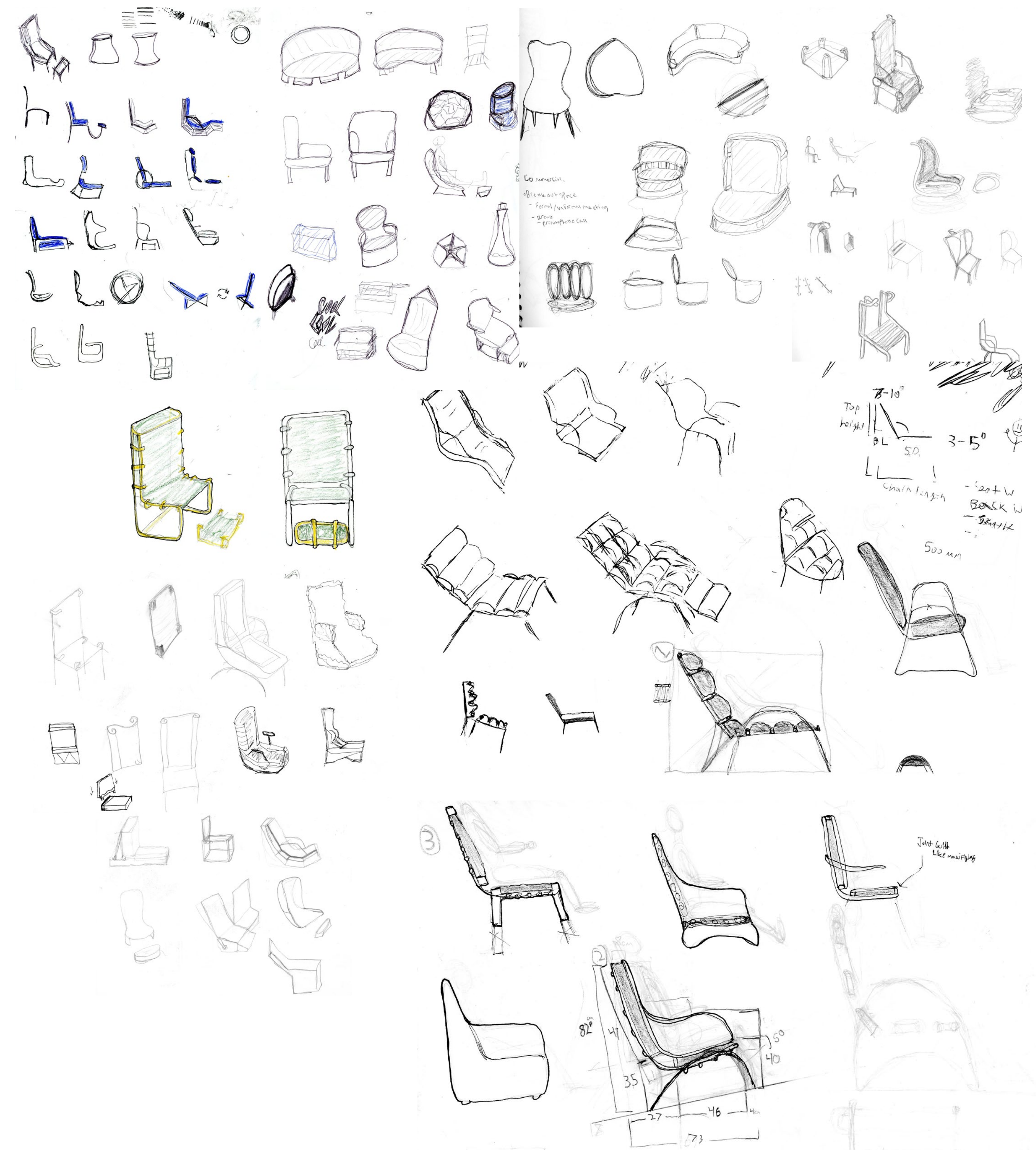
WHY A CHAIR

Simply because I wanted to. Having yet to design and craft a full scale chair, and thinking of them as a right of passage for any aspiring designer, it became a strong ambition.

Throughout the project the question arose "why not base a product off the waste material?" The answer being that **if designers only base products off what substitutable choices are easy or obvious then there would be a lack of ingenuity and full potential when both adopting circularity and transforming waste into raw material.** Therefore sticking to an existing chair design then making the waste work within that design felt as the true testimony for the potential of design circularity.

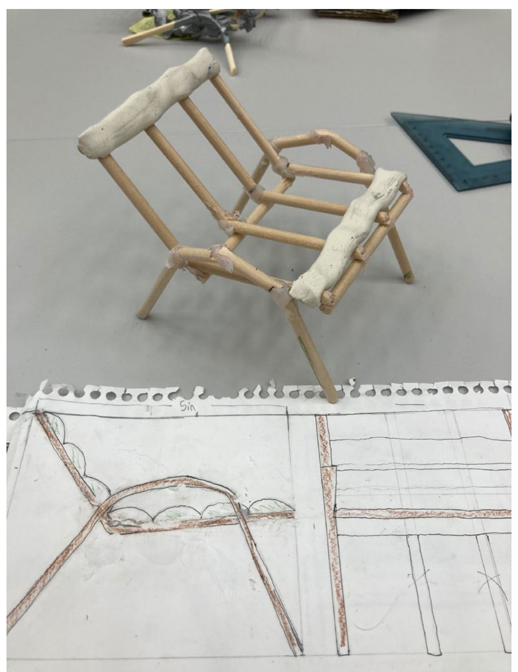
THE ESTABLISHED DESIGN AND PROCESS

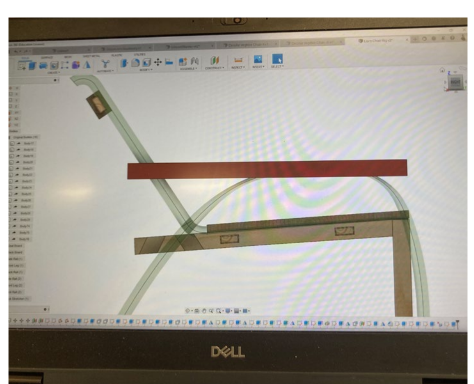
It is important to note that circular design does not only rely on the materials of which it is made up, but also on how to expand the products life as long as possible using a multitude of tactics. Originally, one of them focused on in this design was how to limit different parts, as each part requires different manufacturing. As well as fix-ability, if a product can be easily fixed then it can drastically extend its life. For instance if using glue and nails in a chair design and one part breaks it could make it more difficult to fix just that part, and may resulting in the chair being thrown out. Whereas a chair held together on friction joints alone it makes it easier to fix like popping out a broken leg and repairing.



CIRCULARITY CHAIR
prototyping

Chair design maquette and rig prototype with established dimensions. Crafted two months prior to touching rice hulls, this design became the case study to represent the possibilities of circularity.






A


B


C

D

COMPONENT COMPARISON

A: Rice Hull Concrete, replacing CO2 monster cement

B: Rice Hull plastic, and cushion replacing waste behemoth petrochemical and polyurithane plastic

C: Rice Hull board, replacing resource consuming and forest killing wood

RESULT

Although the final chair design is at 1/6 scale, due to time constraints, and manufacturing resources, it represents the possibilities of circular design. I am pleased with this circular designed chair as it the majority of it is made with rice hulls. Hopefully in the near future this model will become a full scale reality.

PROJECT CONCLUSION
calls to action

RETHINKING OUR WASTE

Although its been said time and time again, our societies and ecosystems are on a brink of chaos due to global warming and over consumption. Leading to toxic and dangerous living conditions for all species on Earth. On an individualistic level we need to be better, however on a product designer and manufacturer level we need to be the best.

Product designers are entering a new era were we can not simply make things because they look cool, nor should we make things that are needed in unsubstantial ways, or at the least try our best to cover all bases, and explore all options on how to reduce waste. Starting with implementing a cultural norm for designers, manufactures, and retail companies in which we adopt circular design methods and consider using a waste to raw material to build our products.

RETHINKING PRODUCT BEAUTY

As it stands, our culture around products are that clean, neat, and beautiful are what help equate to a great product, but beauty is subjective. Consumers have to start excepting that certain materials making up a product look unusual. For instance Lemo plastic looks bizarre and different compared to the normal clean, transparent plastic. However for the sake of our planet and social construct we need to adopt an acceptance, which will lead to an admiration, for materials that are otherwise described as ugly yet serve a greater purpose.

CLOSING REMARKS

Throughout this project I learned the true meaning of what it means to be a designer. It means looking past what you already know, leaving the design realm to enter new realms of industries and communities. During this project I entered the realms of chemistry and farming. Learning a great deal about certain chemicals, theories, and practices, involving both the chemistry field and rice fields. As well as giving me an introduction to being a material scientist.

This project pushed me, teaching me to treat each failure as another form of research. Although most proud of the material samples I produced, as well as with my maquette an overall performance, I am willing to push forward and continue this project until I am sitting in a chair made of rice hulls.

BIG THANKS

I had a great deal of guidance and help throughout each stage of this project, so shout out...

- Frontier AG
- Prof. Debra Glass
- My Brother McArdle
- Eduardo Flores Galindo
- Lab managers Richard Ortiz and Justin Wong
- Ceri Almont
- Reed Fine
- Kevin Rouff
- Dr. Bruce Manning
- Prof. Jennifier Blecha
- My fellow peers