[SEAWEED] FARM TO TABLE

Research Report

Kathryn Larsen

11/05/2022

TABLE OF CONTENTS

1. INTRODUCTION

BLADDERWRACK AND SEA LETTUCE

1.1 PROBLEM STATEMENT

In 2021, the IPCC released a report stating that ongoing sea rise level due to climate change, would be irreversible for potentially hundreds of years (IPCC, 2021). However, they also stated that by reducing carbon dioxide emissions, it is possible to still limit the effects of climate change (IPCC, 2021). In recent years, seaweed farming, and seagrass meadow restorations have emerged as a possible solutions to help capture and embody carbon emissions. When combined with mussel farming, they help the environment further by filtering the water of heavy metals and pollutants (Zeewar, 2021).

As the building industry is responsible for up to 39% of global carbon dioxide emissions (World GBC, 2019), companies like The Seaweed Company have invested in the possibility of using seaweed as building materials, to sequester the carbon for longer term (The Seaweed Company, 2021). The issue is, there is no written comprehensive guide as to how these materials can be applied in a built environment, despite a historical precedent for their use. Furthermore, many resources confuse seaweed and seagrass, which makes possible construction applications even more difficult to research.

1.2 RESEARCH QUESTION

"How can we use seaweed, seagrass and mussel shell waste as resources in the Dutch built environment?"

Fig 1: canal bike with mussel shells and algae growing together

1.3 BACKGROUND

For my thesis at the Copenhagen School of Design and Technology, I investigated the role of eelgrass (a common type of seagrass) in the Danish construction industry, and experimented with creating a prototype of prefabricated seagrass thatching. My previous research did not distinguish clearly between the role of seagrass versus seaweed in construction. Thus, for this thesis, I will focus more on the role of seaweed and mussel shells as materials in combination with eelgrass, as well as the Dutch context for such a construction to be utilized.

Historical precedent of these materials and their uses provides a roadmap of what to test, and where to begin. As previously stated, seaweed was historically used as a binder in construction applications around the world. Seagrass has historically been used as insulation, mattress stuffing, and upholstery (Vandkunsten, 2013).

Calcium carbonate, which can be found in egg shells, was also added to Japanese seaweed lime plaster (Shikkui, 2021). Mussel shells are also composed of 95-99% calcium carbonate, so this provides a basis for experimenting with plaster mixtures (Murphy, Hawbolt, and Kerton, 2, 2018).

In the Netherlands, in the province of Wieringen, seagrass was used to build wierdijken, or so-called "seaweed dikes" during the Middle Ages (Keeton, 2014). Here, the seagrass was applied to the inside of the dike, towards the land-side, and kept in place with wooden poles. This prevented soil erosion of the dike.

Fig 2: traditional Danish "seaweed farmer", Kurt Schierup from Møn Tang, processes dry eelgrass into bales for construction. Eelgrass is a type of seagrass native to the northern hemisphere.

1.3 BACKGROUND

Seagrass was also used to thatch roofs in China for centuries in the Jiaodong Peninsula, yet a recent English-language news article from China Today incorrectly refers to the seagrass construction as kelp, likely due to the fact that locals sometimes call them "kelp houses" (Zhidong, 2019). Other articles, such as one by ChinaDaily, refer to the roofs again, mistakenly as a seaweed construction (2020). The tale-tell sign of a seagrass roof construction are the swaying silvery seagrass blades on photos of the construction, as opposed to large, leafy fronds from kelp, or small vesicular fronds from brown seaweeds.

This example highlights the challenges of researching seaweed versus seagrass in construction applications. In the past, seagrass was commonly referred to as a seaweed in various countries, and mistakenly classified as such. Seagrass, however, is a plant, and seaweed is not. Seagrass has roots, and grows from seeds. Seaweed is a form of algae, and has a holdfast, similar to a barnacle (Norris, 1, 2019). Similarly, blue-green algae, although called algae, is not, in fact related to seaweed. Rather, it is classified as cyanobacteria, a type of bacteria, defined by their strong pigmentation (M.D. Guiry, 2000). The confusion between these three distinct groups and their applications often requires one to understand their biological appearances, in order to distinguish between them, while researching.

This is because despite their similar names, these groups all have vastly different material properties. For example, seaweed tends to rot with repeat exposure to moisture, and will even rot in storage if humidity is above 40% (McHugh, 57, 2003). For this reason, it is prudent to not use it as an insulation material. However seagrass will turn silver, harden, and last for many more years. There are instances of seagrass insulation lasting in wall cavities after over a century (Archipedia New England, 2020).

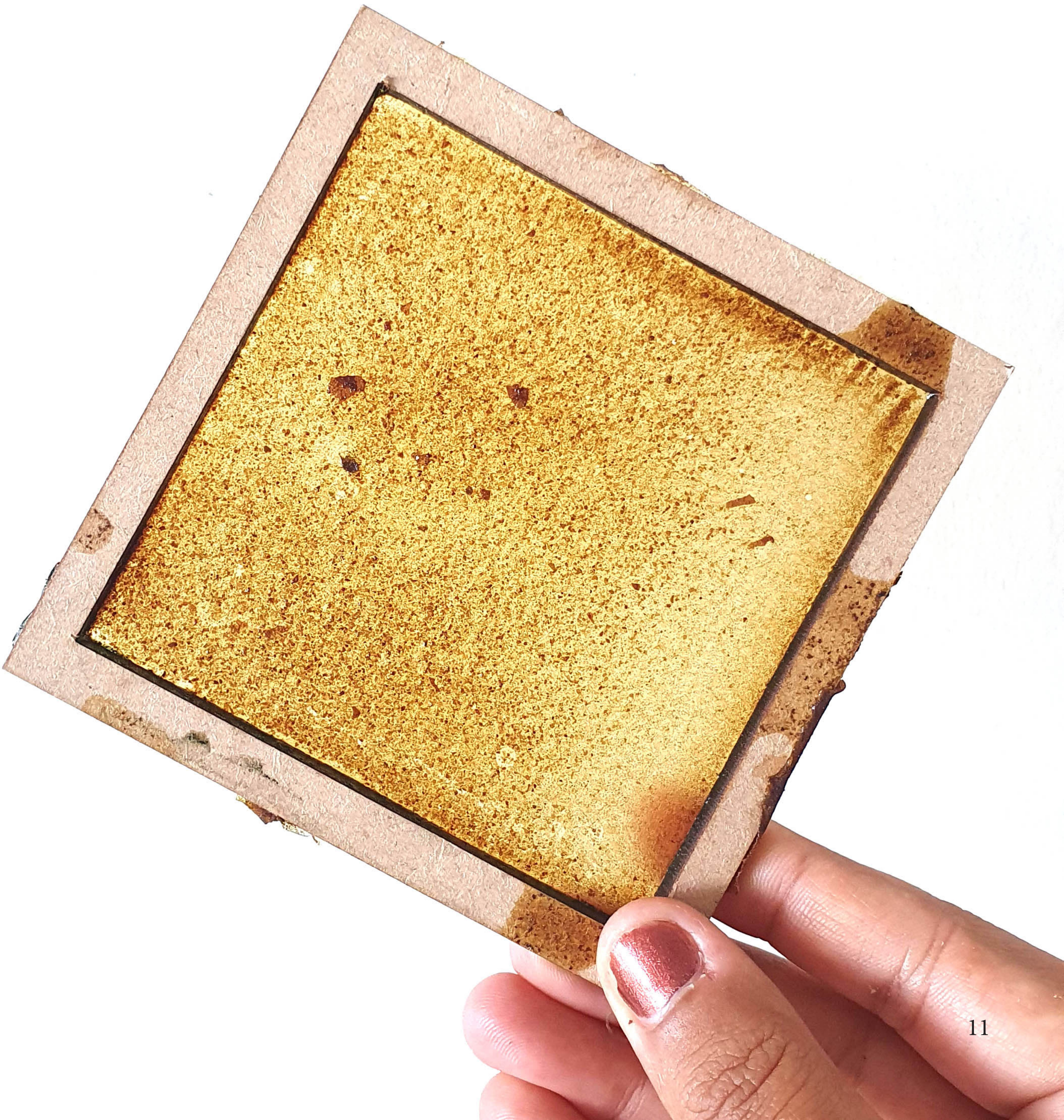
Fig 3: Traditional Læsø "Seaweed House". Like many historical references to "seaweed", the seaweed in this case is actually the seagrass known as eelgrass (Zostera marina).

1.3 BACKGROUND

This is also why on the Danish island of Læsø, a properly thatched seagrass house will last for up to three hundred years (Gardiner, 2020). Cyanobacteria like Spirulina, on the other hand, is sometimes used as a nutritional supplement for iron (Sp2Life, 2021). Its strong green and blue coloring lends itself as a natural dye in material explorations.

There are some newer, more experimental material applications, such as seaweed in bioplastics (Hahn, 2021) and mussel shells in ceramic 3D Printing (Sauerwein, 9, 2020). These could have potential applications in interior architecture, for replacing glass or concrete materials.

Fig 4: Seaweed bioplastic test with dulse seaweed, gelatine, and glycerol



1.4 METHODOLOGY

The primary methodology for this research will be a Material Driven Design (MDD) methodology, which is based in Research Through Design (RtD). Material Driven Design is a newer methodology, that involves designing from the materials as the starting point (Karana, Barati, Rognoli, Zeeuw van der Laan, 1, 2015). In order to design with seaweed, seagrass, and mussel shells, it is necessary to inherently understand and experiment with the materials, by prototyping and letting the materials speak for their use. Only then can one begin to explore the possibilities and potential applications of these materials, as well as their architectonic potential.

Using this research methodology, a material's perceived weakness can become its strength. For example, most seaweed-based glues are very weak, making them unsuitable for resin-composite based applications. However, this weak glue provides an even consistency and workability to traditional Japanese plasters (Holzhueter, 2014), and traditional wood and ceiling paints (Vadstrup, 3, 2010).

Using this methodology, I will produce a range of prototypes and material experiments. From these prototypes, I will develop material applications for use in the built environment, and explore the strengths and weaknesses they have.

I am specifically looking at developing a seaweed-derived bioplastic, seaweed-derived paints, a mussel biobased concrete, and a mud plaster with seaweed glue.

Fig 5: Making process. Photographed by Sarah Tulej.

1.5 LIMITATIONS

Material Driven Design has some drawbacks. When a material is used in an improper fashion or not fully realized, it can cheapen the perceived value of the final result, according to Danish researcher Mette Bak-Andersen (2018, 14). Thus, the limitations of materials should be respected.

As the research conducted for this thesis is done in the architecture faculty, access to testing the strength and performance of materials or constructions is limited. Because of this, for the time being, the results will remain speculative, as further testing on longevity and strength is necessary to confirm their full potential as materials for the building industry

Ethical questions can be raised with Material Driven Design, especially when experimenting for sustainable reasons (Bak-Andersen, 2018). Raw materials might be locally limited, or unsustainably sourced. For example, with regards to wild seaweed in the Netherlands, it is not permitted to harvest any without a license (Verhaege, 2020).

Therefore I have made the decision to source my seaweed and seaweed-based materials from seaweed farmers and suppliers here in the Netherlands, using endemic species, such as Dulse (Palmaria palmata), Irish moss (Chondrus crispus), and Sea Lettuce (Ulva), and I have also arranged for a visit to learn more about a land-farming seaweed practice.

My seagrass comes from Denmark, from a licensed traditional Danish eelgrass farmer. Despite the energy required to ship the eelgrass, harvesting eelgrass in the Netherlands ethically is currently not possible. In the 1930s, the construction of the Afsluitdijk destroyed the conditions necessary for eelgrass to flourish in the Dutch Wadden Sea (van Eerbeek, 6, 2010). There is an ongoing preservation effort by Laura Govers, who believes there is not enough healthy eelgrass in the Netherlands to supply the construction industry (Tekath, 2020).

Fig 7: Fresh sea lettuce, from Amsterdam-based "Seaweed Tech" grow tanks. By sourcing seaweed from licensed farmers for material experiments, ethical harvesting can be ensured.

2. SHELLCRETE - A SHELL-BASED BIOCONCRETE

Fig 8: Shellcrete samples, made from mussel shells and cockle shells. Note the color difference between the white mussel shellcrete and the brown cockleshell-crete

2.1 BACKGROUND

Mussel shells are a thinner shell than cockles, and when heat is applied briefly, crush very easily by hand. However, when put into a kiln, and heated to over 800 degrees celcius, the shells will release carbon dioxide, disintegrate, and form calcium oxide. Calcium oxide is also known as quicklime, and is one of the oldest building materials known to man. Called "shell ash", few studies have investigated replacing cement with a percentage of quicklime (Wan Mohammad, 2021). The main issue with shell ash, is that it lacks the higher amount of silicates that allow for a true concrete replacement (Dean, 2017). When potentially combined with kaolin clay, which is high in silicates, a more concrete-like material can be produced. This is the chemical basis of hempcrete (Magwood, 2016).

Due to faculty limitations, it was not possible to gain access to a kiln to experiment with quicklime. However, by heating the mussel shells at 200 degrees in an oven, the shells were able to be crushed, in a methodology recommended by TU Delft researcher Mariet Sauerwein. By grinding them in a blender and sifting, an aggregate could be created, as well as a finer powder. The heating and grinding of the shells appeared to increase the cementations quality of the material, however, due to testing limitations preventing the use of compression testing, it was difficult to test this quantitatively.

The mussel shell "cement" and shell aggregate were combined in a series of experiments testing different amounts of seaweed glue binders from dulse seaweed, spirulina algae, and gelatine.

2.2 TESTS

Seaweed Glue Mixture 1:
120g dulse, powdered
240 ml water water
10g gelatine

M01
25 ml Seaweed Glue Mix 1
50 ml mussel cement

This ratio produced a relatively dry, crumbly mix. At first, it was assumed that this would be unsuccessful experiment, due to the how crumbly the mix was, however, it ultimately was the strongest combination. The addition of gelatine increased the strength of the seaweed glue.

Seaweed Glue Mixture 2:
120 g dulse, powdered
240ml water

M02
50ml Seaweed Glue Mix 2
50 grams mussel cement
50 grams mussel aggregate

This produced a wetter mix, and the seaweed glue from the dulse seaweed was tacky upon touch. Although the mixture gelled, it did not set solidly, and the sample cracked very quickly.

Seaweed Glue Mixture 3:
240ml water
5g agar agar
5g dulse flakes
5g spirulina

M03
50 grams Seaweed Glue 3
50 grams mussel shell "cement"
50 grams mussel shell aggregate

This initially seemed like the perfect ratio. It gelled and dried hard. However, the spirulina and agar-agar was too brittle long-term, and after a month, the sample cracked under pressure.

Fig 9: Shellcrete results from testing, with a mussel shell base

2.3 SHELLCRETE BRICKS

Based on these tests, when scaling up, the M01 ratio was adapted. For larger scale bricks, the mixture was cast similarly to concrete. 25% more glue was added to create a "wetter" mix to allow for a clean cast with smooth edges, The more crumbly mixture tended to have rounded corners and the mix had to be stamped into the mold, in comparison. The bricks had to be turned every day while drying, and took a month to cure entirely.

When the M01 ratio in a brick is created, it can hold the weight of one eighty-kilogram adult standing on it. A compression strength test was scheduled for January 2022, however due to the subsequent COVID lockdown, it was no longer possible to test at this date. Future testing will involve trying to get hard data regarding the strength of the brick for potential construction applications.

Fig 10: M01 Shellcrete Test

2.4 TECTONIC STUDY

In collaboration with fellow TU Delft student Rianne Reijnders, some of the sargassum fibers from Climate Cleanup were manually pressed into leemsteen (dutch unfired clay bricks).

Using a similar principle to adobe blocks, seagrass was also combined with high quality clay and pressed into an insulating block. The idea to create a seagrass block came from my years of research on seagrass as a material, as many people I have spoken to have expressed concerns about the practicalities of applying seagrass as a loose infill application, without resorting to prefabricated wall elements. The brick infill solution makes it easier to install seagrass as insulation, which further incentivizes its use as an application, especially for renovation projects.

Together with the shellcrete bricks, these materials were assembled in a 1:1 scale masonry application. The shells used and the type of mortar have a significant impact on the tectonics for this material application. If Portland cement is used, it is possible to create a prefab element with the shellcrete bricks, as it they are relatively loadbearing. This will also create a visible seam where the walls connect on site. However, the decision to apply this material with prefabrication also means that the shellcrete bricks cannot easily be disassembled and reused, as is the case with masonry and lime-based mortars.

In this case, a natural clay mortar was used for the model to show the goal of designing for disassembly. The mortar was combined with 4 parts sand, 2 parts clay, 0,1 parts seaweed glue, and 1 part ground shell aggregate. The mortar took on the coloring of the clay utilized- when a white clay was used, the mortar was white. When a yellow clay was used, the mortar was yellow. The appearance of the shellcrete is also dependent on the type of shell used. In order to scale up, building grade cockle shells were used for the 1:1 scale model. This resulted in bricks that were dark brown in appearance. When the shellcrete was made from mussel shells, the resulting mixture came out speckled and white. This would have an impact on the aesthetic appearance of the architecture as a result.

Fig 11: Tectonic Study
From Left to Right: Sargassum Leemsteen, Seagrass Insulating Blocks, Shellcrete Bricks

3. SEAWEED-BASED BIOPLASTICS WITH DULSE

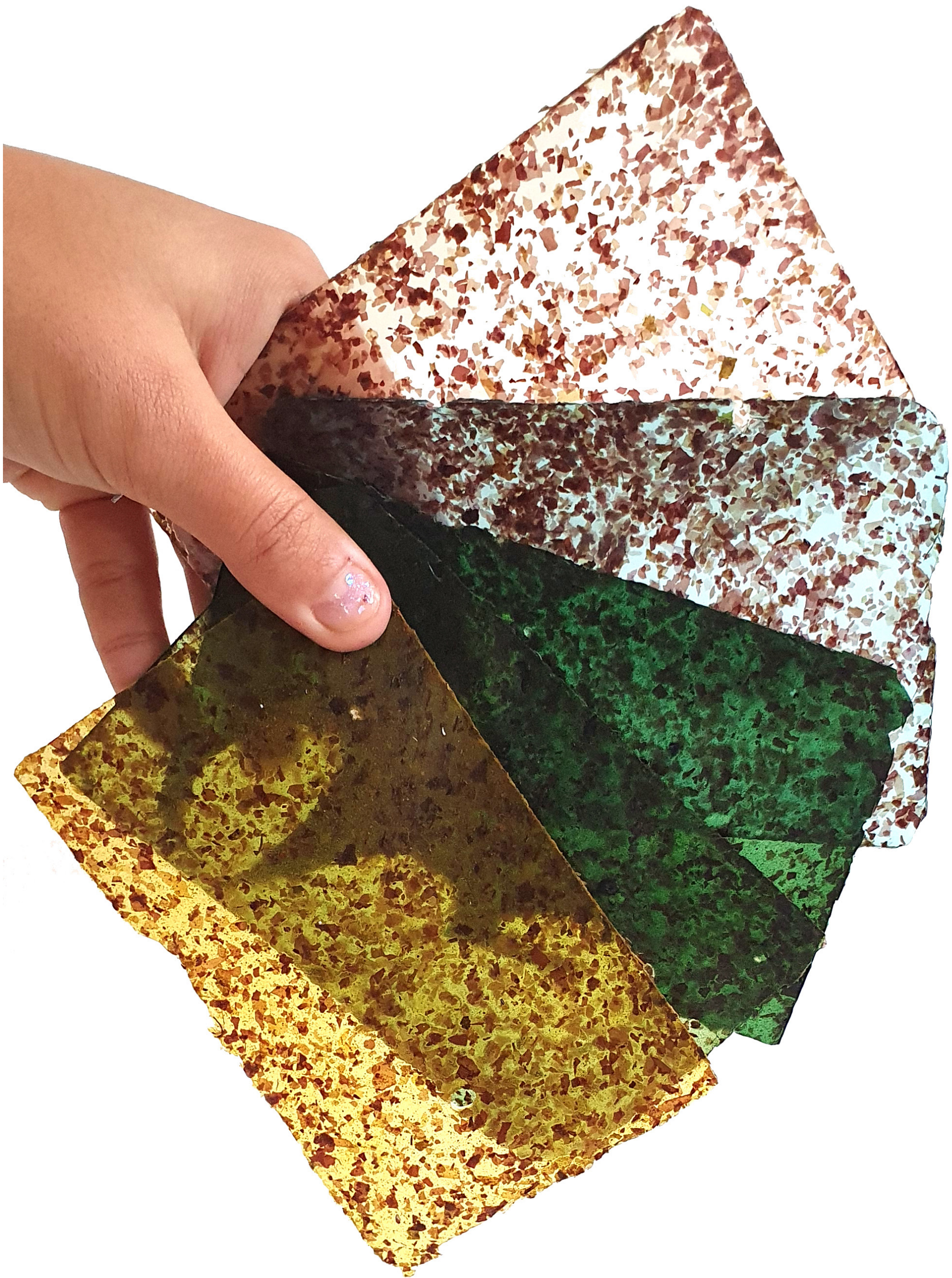


Fig 12: Bioplastic samples with different natural dyes. Yellow is turmeric, blue and green are spirulina (microalgae)

3.1 BACKGROUND

Bioplastic, as defined for this research report, refers to a material with plastic-like qualities, from non-petroleum based sources. In many cases, the ratio requires a base of a glue or starch, combined in water with a plasticizer to increase the flexibility of the material. For the case of these experiments, vegetable glycerin was added to the mix as a plasticizer in some cases. The extracted polysaccharides from algae, including alginate, agar-agar and carrageenan, have already been established in bioplastic blends on open-source websites like Materiom, however few experiment with intact seaweed.

Many of the seaweed glue blends from the Mussel Shell-crete experiments were adapted to see if they could become a bioplastic. Seaweed Glue Mix 1 formed a proper bioplastic, but the dulse alone in Seaweed Glue Mix 2 was unable to gel strongly enough to produce a successful plastic film. This demonstrated that the polysaccharides in the dulse seaweed alone, without extraction, were not strong enough to create a successful bioplastic. After this analysis, the boiled dulse was combined further with polysaccharides like carrageenan and agar-agar to strengthen the mix. In addition to this, natural dyes from turmeric, spirulina, and avocado pit were tested.

In order to successfully create clean, flat sheets of bioplastic, the mixture was poured into a laser cut frame on top of a silicone baking mat. After the mixture had gelled and slightly evaporated over a period from four hours to two days, the entire frame could gently be peeled from the mat. Many students with access to facilities for material fabrication will make use of glass baking trays and a dehydrator to process bioplastic, however this was not possible for this research, due to faculty access restrictions. This lead to a heavy degree of error when testing the bioplastic, as peeling the mixture from the baking mat too soon could mean the center of the gel tearing into pieces, and peeling too late could result in a dried, sticky mass separated from the frame. The window frame for this process was also largely dependent on the heat and humidity in the room while working, and would fluctuate. Eventually through practice and many failed experiments, it was possible to evaluate the readiness of the material by touching the surface. If the surface resisted, it was gelled enough to withstand removal. If it stuck or left residue on the fingertip, it was not ready.

3.2 TESTS

Seaweed Bioplastic 1 (based on Seaweed Glue 1)
120g dulse, powdered
240 ml water water
10g gelatine
3ml vegetable glycerin

This was a successful ratio. The bioplastic dried after two days and did not split in the frame or warp. However, due to the presence of glycerin, the texture was tacky when dried, and would easily stick to itself when folded.

Seaweed Bioplastic 2
240 ml water water
12g carrageenan kappa
3ml vegetable glycerin
10g dulse flakes

Another successful ratio, however unlike the Seaweed Bioplastic 1 mix, which had working time to be poured into a mould and set, the carrageenan bioplastic set almost immediately. Rather than pouring into a frame, it could be free-poured onto a mat, where it set. Drying this as a result was challenging, however resulted in a very nice, flexible and strong bioplastic with less tack than the Seaweed Bioplastic 1.

Seaweed Bioplastic 3

240ml water
5g agar agar
5g dulse flakes
5g spirulina
3ml vegetable glycerin

This ratio attempted to make use of spirulina microalage as an extra binder and dye. However, the presence of spirulina destabilized the strength of the bioplastic. With both blue and green spirulina, holes formed as the bioplastic dried. Adding 5g of sugar helped stabilize the mix.

Fig 13: Various bioplastic tests with different dyes

3.3 TECTONIC STUDY

The ability to dye the bioplastic different colors and manipulate the pliability of the material through the addition or exclusion of a plasticizer created an interesting effect when held up to the light. Based on this, the tectonic study focused on creating a self-lit structure for the bioplastic that could demonstrate this effect.

Through observational sketching around Delft, a relationship was observed between the stained glass in the Netherlands and the potential application of this material in an architectural context. Unlike stained glass, the bioplastic is 100% biodegradable when buried for 3 months, and is not waterproof. The dyes will also fade with exposure to UV light. Thus an interior application was prioritized, in the form of a lamp, that reminds the viewer visually of a stained glass application.

There is a potential to apply a biobased coating for waterproofing, such as the coatings used by the Exploded View pavilion (Frearson, 2021). However, this is still not a suitable replacement for a window that is thermally rated and would relegate the material to only being used in a pavilion-type application architecturally.

As a result, the largest architecture potential for this material is for use in ornamental application, in interior design-related products. The tectonic potential of this material comes from the texture and makeup of the material, by experimenting with colors and embedding different seaweed flakes in the mix.

Fig 14: Zeeglas Lamp

4. SEAWEED CLAY PLASTER

Fig 15: Seaweed clay plaster with seaweed spirulina paint

4. 1 BACKGROUND

In Japan, seaweed glue has long been used in traditional Japanese clay and lime plasters. It was not used to glue the mix together, but to improve the workability of the mix (Holzhueter, 2014). The glue improves the viscosity of the mix, by retaining moisture. This means a plasterer does not constantly need to remix while applying the plaster to a larger surface area. However, identifying the seaweed in this construction application proved to be difficult at first, as it is commonly referred to in Japanese as tsunomata. According to plastering master Emily Reynolds, tsunomata is a red algae in the same genus as irish moss (Reynolds, 2009). Although tsunomata is not native to Europe, irish moss is.

There were two goals with testing seaweed in combination with clay. The first was to understand how the addition of seaweed glue impacted the clay mix itself as well as the application. The second was to test whether or not the addition of small particles of sargassum fibers would rot in the clay, or if they would stabilize the mix similar to hay. Seaweed rots in excess humidity, however clay is a known humidity regulator. Thus, in combination, they could suit each other in a construction application.

Sargassum in particular is a nuisance for many countries, including the island of Sint Maarten. When excess seaweed washes up and is left to rot, it can be hazardous for human and marine health due to the excessive hydrogen sulphide produced (Vos, 2016). Clay is a relatively accessible building material around the world, so for countries struggling with invasive or excess sargassum, integrating it into this application could prove to be a productive solution.

4.2 PREPARATION AND CONTROL

In order to provide these experiments with a proper control, I enrolled in a clay plastering course at Tierrafino. It is difficult to experiment with different natural building techniques without first gaining the kinetic knowledge from other experts. With clay plaster in particular, the water ratio is dependent more on the texture and feel. The plaster should be wet but not liquid for an ideal application, with the consistency of American cake batter. For small scale tests, the plaster was applied in two thin layers to a sanded fermacell board.

To create the starting ratio of the plaster, plasterer Kyle Holzhueter's advice was followed. He states to mix fine, sifted clay and sand in a 1:1 ration, and then add seaweed glue at a rate of 1kg per bucket of dry clay-sand (Holzhueter, 2014). It was not clear what the quantity of 1 bucket was, but it appeared to be a significantly less amount so I added clay, sand, and glue in a batch until the consistency felt right.

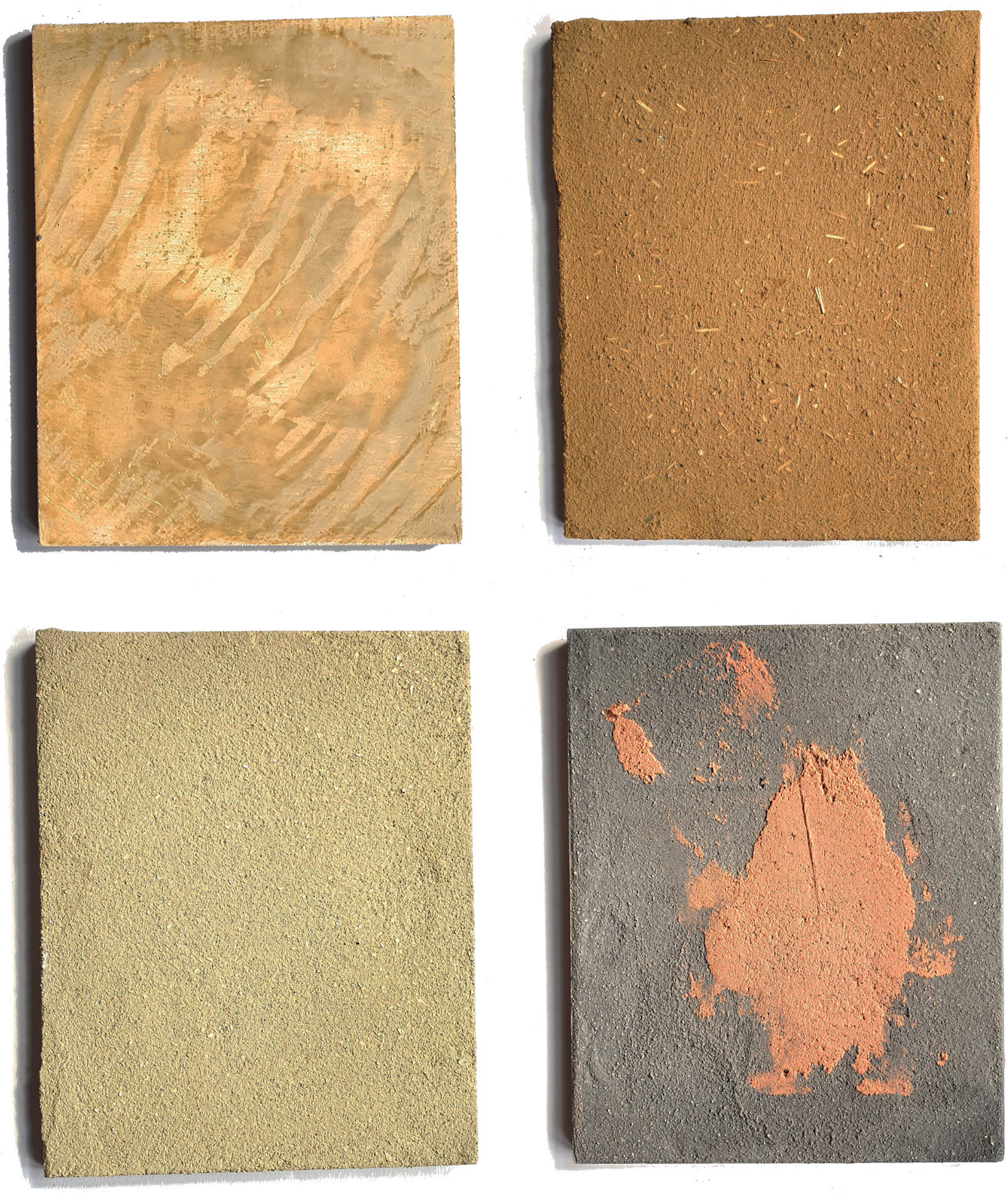


Fig 16: Control with Tierrafino clay plaster products, supervised by a master plasterer

3.2 TESTS

Seaweed Clay Plaster 1

600g clay
600g sand
100ml boiled irish moss glue
Water

This initial mix cracked, however it was due to two factors: applying the clay plaster too thickly, and not troweling the finish fast enough. After applying the mix extremely thinly in two layers and troweling the finish, the clay plaster was much smoother, and had adhered better to the surface. When adding the seaweed glue, the mix became far spongier, and required more water to thin the mix to a workable blend. This is likely due to the gelling properties of carrageenan in action.

Seaweed Clay Plaster 2

600g clay
600g sand
200g dried, crushed sargassum
100ml boiled irish moss glue
Water

This experiment used the same mix as before, but added crushed sargassum. The addition of sargassum made it very difficult to apply an even layer and resulted in a very textured appearance. However, the addition of the sargassum made for a much smoother, more crack-resistant application. When the sargassum fiber is added to the mix, a sponge finish on the plaster is much more successful than a trowel finish.

Fig 17: Top left: the wet plaster prepared, Top right: the first failed seaweed glue test
Bottom left: sargassum and seaweed glue, Bottom right: seaweed glue with seaweed paint

3.3 TECTONIC STUDY

For the tectonic study, a timber frame application was utilized. Here the plaster was applied in two different ways: on a fermacell board, as before, as well as on chicken wire over a direct infill of seagrass. This is an application similar to hay bale building, and has never been studied with seagrass before.

The sargassum plaster was utilized, as in a larger surface area, it is easier to work with. The fermacell layer of plaster performed similarly as in the tests. On the chicken wire, the first layer of plaster cracked along the wire lines. The second layer smothed considerably the cracks on the surface, making this a viable application. Compared to the fermacell board, which is a hard surface, applying the clay plaster evenly on the seagrass was much more challenging due to the movement and transition from structural wood to bouncing seagrass, however once the surface is adequately covered, it is a smooth effect.

From a tectonic standpoint on orthogonal geometry, the effects appear negligible, however with the chicken wire application, it may be easier to make curved and organic construction shapes.

Like with the shellcrete, a different variety of clays produce different colors. It is possible to gain a different experience with the same clay plaster, just by utilizing a clay with a different color. The color comes from the minerals in the clay. For these tests, I used a neutral white clay, as it corresponds with most interior wall finishes in the Netherlands.

Fig 18: Top: Sargassum plaster with seaweed glue on fermacell board
Bottom: Sargassum plaster with seaweed glue on chicken wire mesh over seagrass

5. SEAWEED PAINT

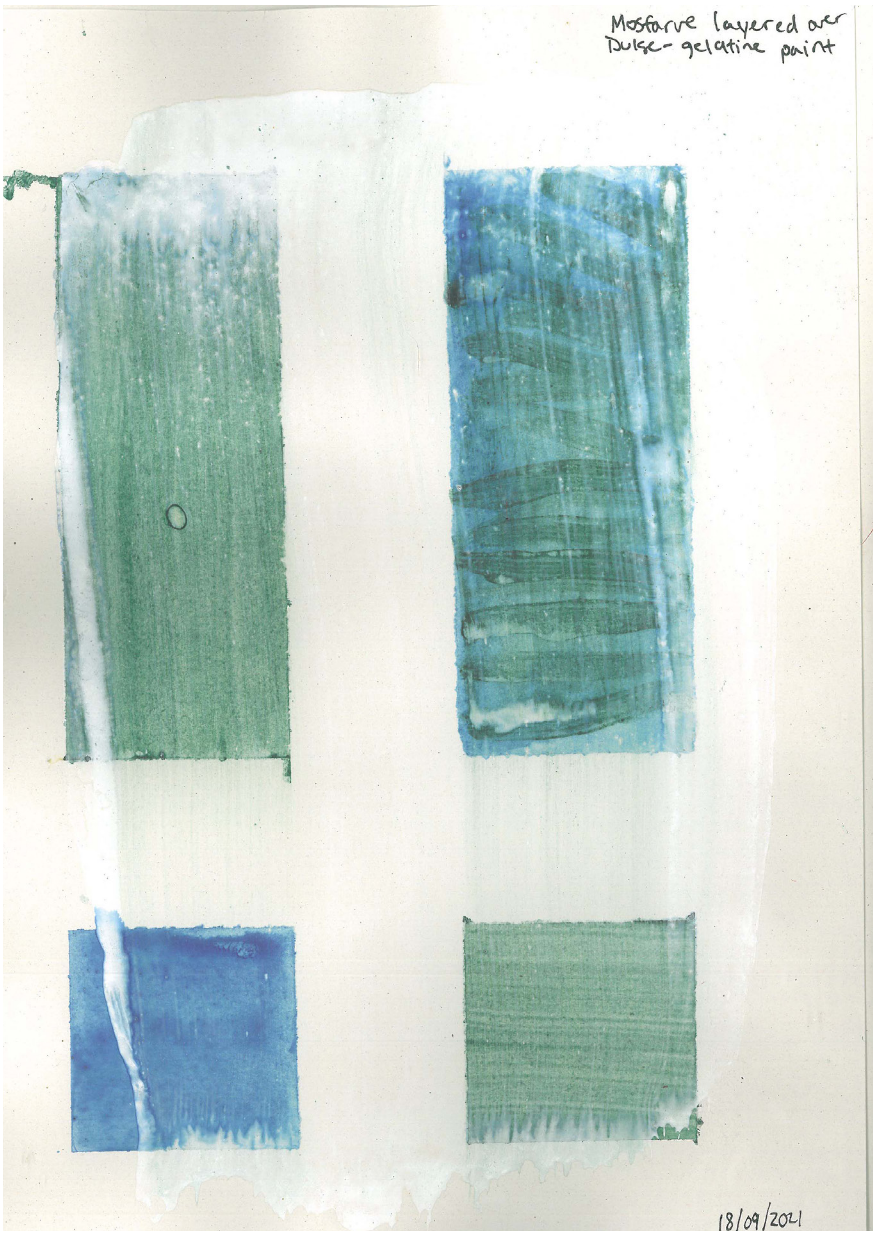


Fig 19: Mosfarve and dulse seaweed paint layered.

5. 1 BACKGROUND

Irish moss, the species utilized for the clay plaster, also has a long tradition of being used in craft applications in Europe. Before the 1960s, Danish wall paint was typically composed of a glue base, and a pigment for the color. In the case of mosfarve, literally moss color, the pigment was chalk. Mosfarve was traditionally only used for whitening ceilings, as Irish moss produces a very weak glue. However, this white glue provides a strong advantage in ceiling paint. The effect it produces is an even, matte white on flat surfaces, and it can easily be removed by washing the surface with cold water (Vadstrup, 2010).

There is very little literature on why Irish moss over other seaweeds was chosen to make paint in Denmark, especially as it has such a weak binding application. It could be due to the high carrageenan content in the irish moss, as opposed to agar-agar. The carrageenan in irish moss was historically used as the base for paper marbling across Europe in the 19th century, and irish moss was also used to size yarns for weavers (Aschoff, 1885). Perhaps from this already-existing artisanal use of the seaweed, it evolved to be used as a paint base in Denmark.

5.2 TESTS

Mosfarve - Stabilized

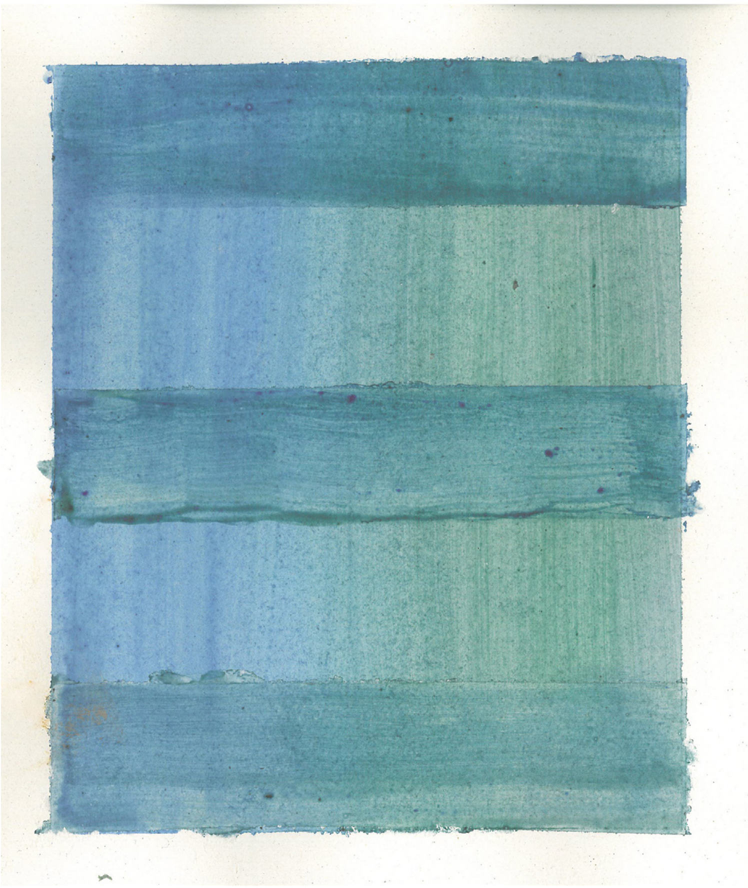
50 g irish moss glue
250g wettened chalk
5-10g spirulina, blue or green

The traditional ratio consists of 1 part irish moss seaweed glue to 5 parts wettened chalk (Vadstrup, 2010). However, adding spirulina to create different pigmentations stabilized the recipe and prevented any chalk transfer. The natural binder in spirulina adds strength to the irish moss glue, and results in a beatufiul pastel color that does not come off on the fingertips while touched. It is very important to not heat the seaweed glue if using carrageenan as an extract rather than raw seaweed, as it will create chalk jelly, rather than paint.

Seaweed Watercolor

50g dulse flakes, boiled and strained
250ml water
5-10g spirulina, blue or green
2ml glycerol

This paint uses dulse as the base, but combines it with different microalgae as paint pigments. The lack of chalk creates a glossy, transparent effect that is very nice on wood. Glycerol or honey acts as a plasticizer again to help with the diffusion of the paint. Adding 2g gelatine also incresase the strength of the paint for various surfaces.



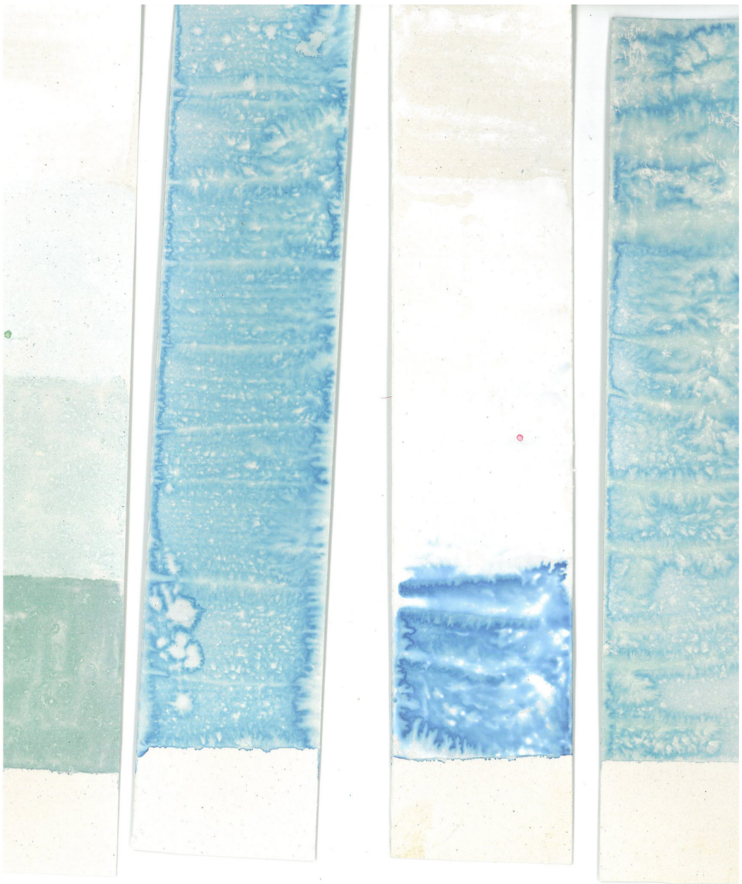


Fig 20: Top: Seaweed watercolor, Bottom: Mosfarve (with spirulina pigment)

5.3 APPLICATION STUDIES

Applying paint in a tectonic fashion is less applicable, as it is a finish rather than a construction technique. To study its potential, I applied different variations of paint along a variety of surfaces, including wood, clay plaster, shellcrete, and paper. After these applications, it was clear why these formulations using animal and seaweed glue were so commonly used historically for building facades and interiors.

The paint applies either opaque or semi-transparent on surfaces, and bonds thoroughly. The undertones of the material impact the way the color is perceived for the seaweed watercolor, however due to the chalk in mosfarve, the application is quite opaque.

It was also possible to experiment artistically with the paint. The second paint was named a "watercolor" because it was possible to work with in a watercolor fashion, and blended thoroughly with water. The same paint also applied well as an ink for linocut block printing, and silkscreen printing.

Fig 21: Application Studies of the seaweed paints, Top left and right: wood stain
Bottom left: linocut print, Bottom right: shellcrete glaze

6. CONCLUSION

Seaweed, seagrass and shells are all effective building materials, rooted in our history and traditions. However, they all have distinctive properties and applications.

Red seaweed works best as a glue and in combination with other matierals, such as chalk and clay. Brown seaweeds work well as a potential fiber application for plasters. Seagrass is an excellent source of insulation, and the Zostera marina variety can be used for thatching. Shells can be crushed to create aggregates, heated to increase their cementitious nature, and turned into quicklime.

These are solutions that can also be combined with conventional materials, as demonstrated- with wood, fermacell board, and portland cement mortars, among others. These in-between applications are necessary baby-steps to adapt builders and contractors to this new, old way of building.

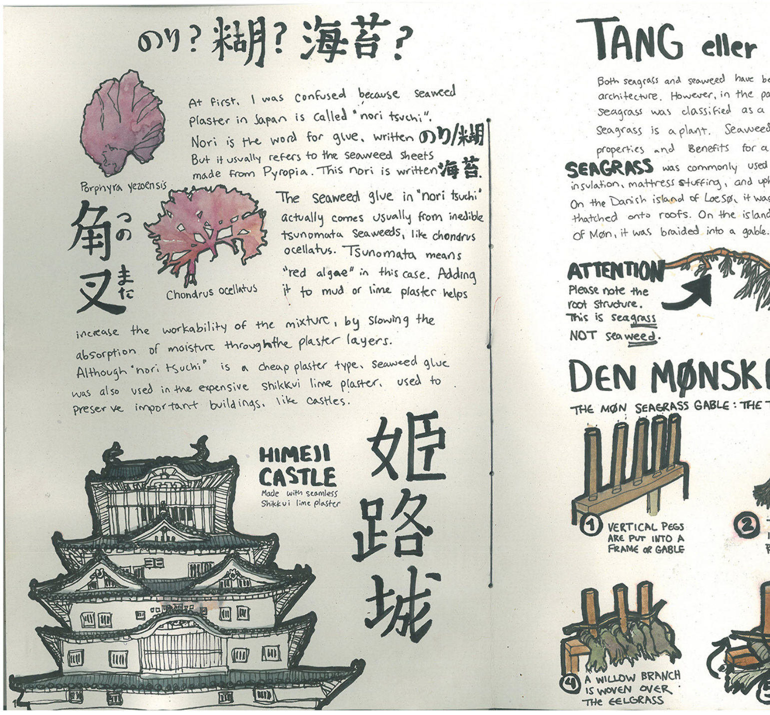
Each of these applications may be more labor intensive than conventional materials today, however conventional materials also hold a hidden cost to our environment. Eventually architects and builders may have to pay for this hidden cost in the form of carbon taxes, and thus a plaster application or seagrass insulation using local species suddenly becomes much more applicable to save on energy.

At the end of the day, these construction applications will only sequester carbon for as long as they are in use. This is why, when possible, combining them with strategies like designing for disassembly, or circularity, will increase their sustainable impact and make a greater difference.

Fig 22: Material Spread

Fig 23: Material Spread

Fig 24: Material Spread



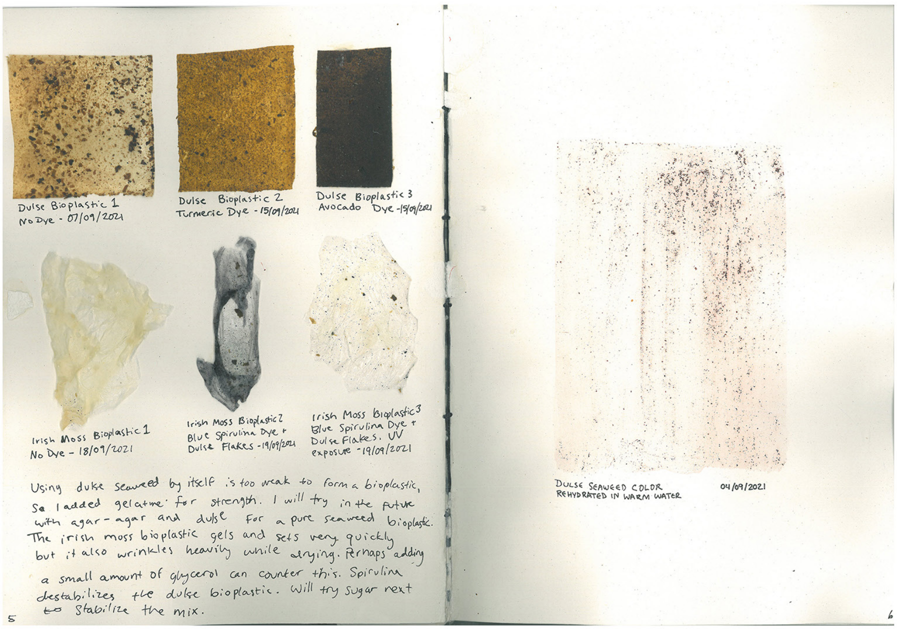


Fig 25: Seaweed Sketchbook and Lab Book, select pages. Handmade bound in seaweed, with Favini Alga Carta seaweed paper.


SØGRAES?
en historically used in Danish
st, like in the Netherlands,
seaweed. There is a difference:
is not. Both have differing
construction.
for
olstry.
Zostera marina
E GAVL
THATCHING TECHNIQUE
AS DESCRIBED TO ME BY KURT SCHIERUP, OWNER OF MØN TANG
THE EELGRASS
S TWISTED INTO
OPES
3 THE EELGRASS IS WRAPPED AROUND THE PEGS
THE EELGRASS IS WRAPPED OVER THE TWIG, AND A NEW TWIG IS WOVEN ON TOP. REPEAT.
2
MOSFARVE
DANISH SEAWEED PAINT
In Denmark, paint for both the interior and exterior historically consisted of a glue, mixed with pigment. One popular application for ceilings utilized seaweed glue, made from the red algae commonly known as Irish Moss. The seaweed was boiled into a glue, and mixed with chalk for a white finish. The seaweed glue was weak enough, that the paint could be removed with cold water.
THE RECIPE
Center for Bygningsbevaring RAADVAAD
1 PART BOILED SEAWEED GLUE
5 PARTS CHALK
Let the chalk sit in water for a few hours, or overnight. If the seaweed glue is too thick while mixing, heat it up to aid in integration.
Chondrus crispus
Result: Do not cook the powdered seaweed! Simply dissolve in water before adding to chalk. Sample here is attempt #2. Sample #1 was chalk jell-o.
Application technique is important to reduce streaks.
3.
SEAWEED
PAINT
Dulse + gelatine + glycerol + spirulina
4


BLADDERWRACK, NATIVE TO THE NETHERLANDS
14


SPIRULINA INK • MUSSEL
15
BLADDERWRACK AND SEA LETTUCE
16

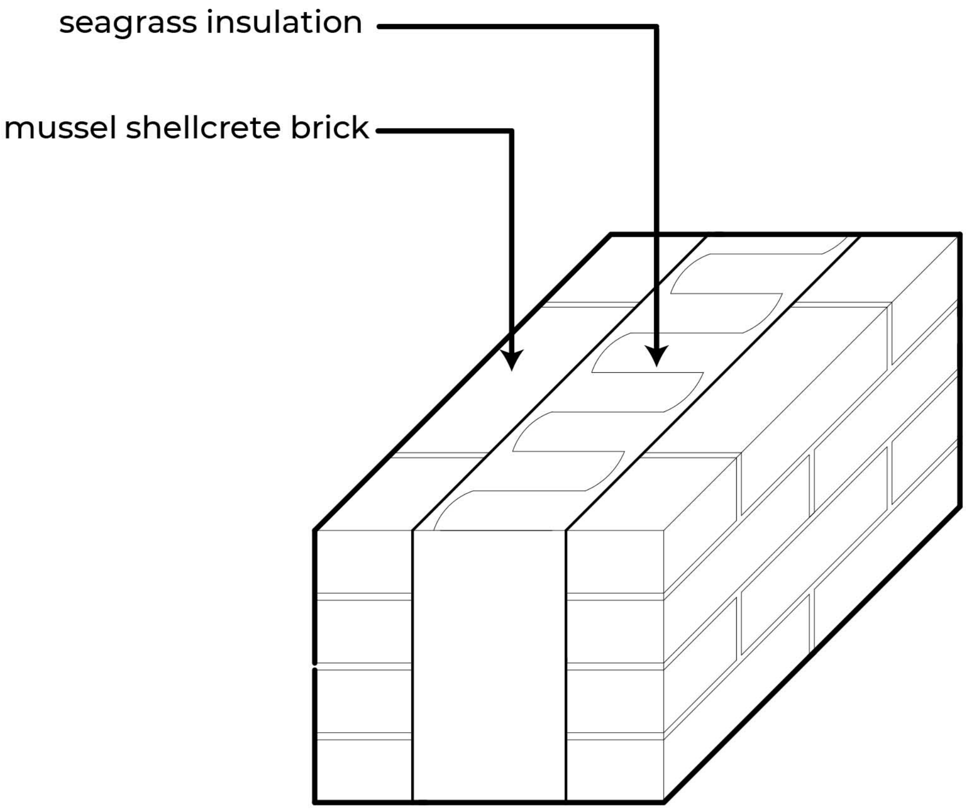


Fig 26: Masonry Construction

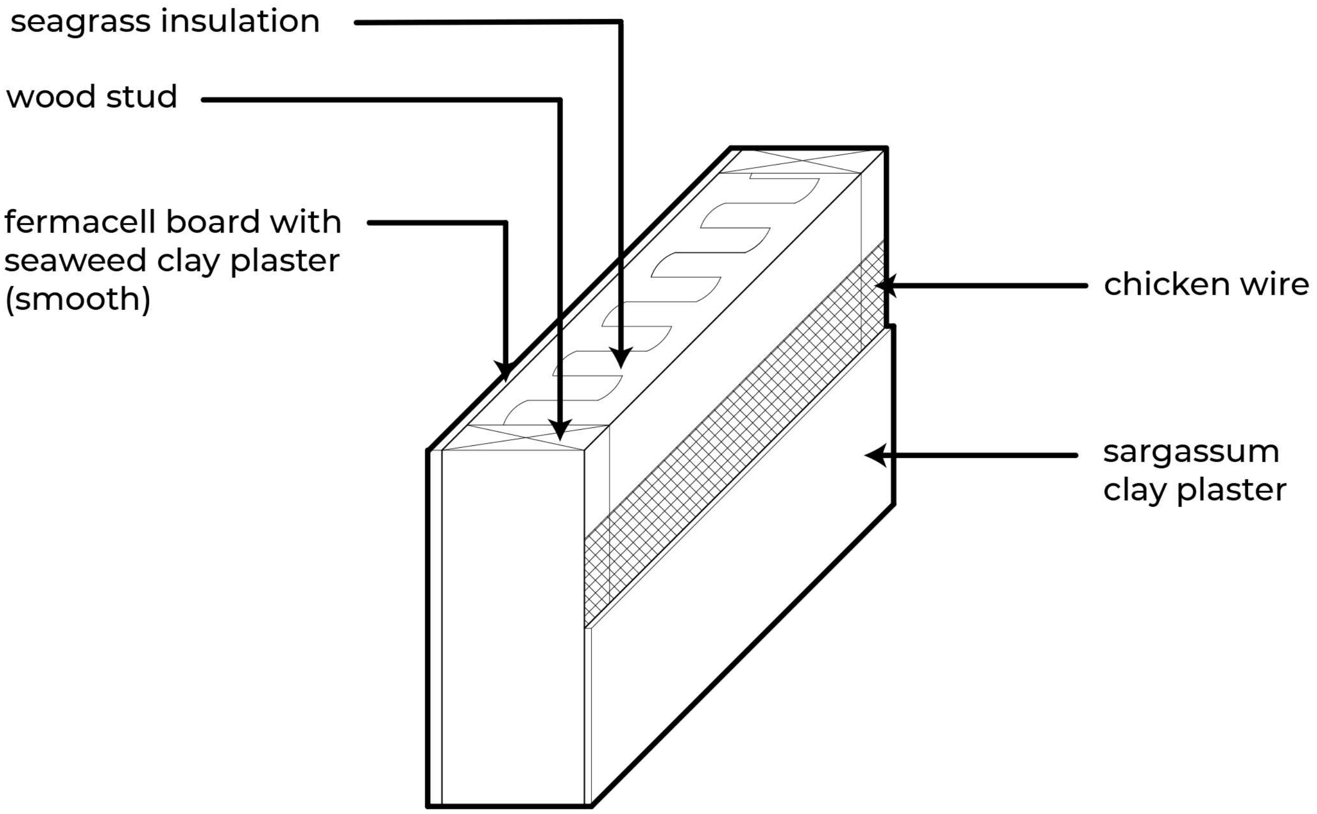


Fig 27: Timber Frame Construction

7. REFERENCES

Amy Frearson | 20 October 2021
Leave a comment. "House Built from 100 Different Biomaterials at Dutch Design Week." Dezeen, 24 Oct. 2021, https://www.dezeen.com/2021/10/20/biomaterials-house-dutch-design-week-biobased-creations/.

Aschoff, Christian. "Die Retro-Bibliothek: Nachschlagewerke Zum Ende Des 19. Jahrhunderts." Retro, https://www.retrobibliothek.de/retrobib/seite.html?id=103142.

"Ar6 Climate Change 2021:the Physical Science Basis." Sixth Assessment Report, www.ipcc.ch/report/ar6/wg1/.

Architectural Seaweed, vandkunsten.com/en/projects/seaweedhouse.

Bak-Andersen, Mette. "When Matter Leads to Form: Material Driven Design for Sustainability." Temes De Disseny, 2018, raco.cat/index.php/Temes/article/view/343481.

"Das Wundermaterial Aus Dem Meer - Bauen Und ARBEITEN Mit Seegras." Deine Korrespondentin, 1 July 2021, www.deine-korrespondentin.de/das-wundermaterial-aus-dem-meer/.

Dean, Signe. "Why 2,000 Year-Old Roman Concrete Is so Much Better than What We Produce Today." ScienceAlert, https://www.sciencealert.com/why-2-000-year-old-roman-concrete-is-so-much-better-than-what-we-produce-today.

"Eelgrass Insulation." Archipedia New England, www.archipedianewengland.org/eelgrass-insulation/.

Gardiner, Karen. "Denmark's 300-Year-Old Homes of the Future." BBC Travel, BBC, www.bbc.com/travel/article/20200805-denmarks-300-year-old-homes-of-the-future.

Hahn, Jennifer. "Phillip Lim and CHARLOTTE McCurdy ADORN COUTURE Dress with Algae Sequins." Dezeen, 25 Feb. 2021, www.dezeen.com/2021/02/22/charlotte-mccurdy-phillip-lim-algae-sequin-dress-onexone/.

Hekkert, Paul, and Elvin Karana. "Designing Material Experience." Materials Experience, 2014, pp. 3–13., doi:10.1016/b978-0-08-099359-1.00001-1.

7. REFERENCES

"Home." Materiom, https://materiom.org/.

"Information on Marine Algae." The Seaweed Site, www.seaweed.ie/algae/blue-green-algae.php.

Larsen, Kathryn. "Seaweed Architecture." KEA Københavns Erhvervsakademi, 2018.

"[Seaweed] Farm to Table." Studio Kathryn Larsen https://kathrynlarsen.com/

Magwood, Chris. "Hempcrete Ingredients: Keeping It Local." Green Builder, https://www.greenbuildermedia.com/buildingscience/hempcrete-keeping-it-local.

Material Driven Design (Mdd): A Method to Design for ... www.researchgate.net/publication/277311821_Material_Driven_Design_MDD_A_Method_to_Design_for_Material_Experiences

McHugh, Dennis J. A Guide to the Seaweed Industry. 2003, www.fao.org/3/y4765e/y4765e.pdf.

Murphy, Jennifer N., et al. "Enzymatic Processing of Mussel Shells to Produce Biorenewable Calcium Carbonate in Seawater." Green Chemistry, The Royal Society of Chemistry, 30 May 2018, pubs.rsc.org/en/content/articlelanding/2018/gc/c8gc01274a.

"New Report: The Building and Construction Sector Can Reach Net Zero Carbon Emissions by 2050." World Green Building Council, 2019, www.worldgbc.org/news-media/WorldGBC-embodied-carbon-report-published.

"Nori-Tsuchi: Clay, Sand and SEAWEED GLUE." Japanese Plastering, japaneseplastering.blogspot.com/2014/06/nori-tsuchi-clay-sand-and-seaweed-glue.html.

Norris, Lori. "What Causes Seaweed to Grow?" Home Guides | SF Gate, 17 Nov. 2020, homeguides.sfgate.com/causes-seaweed-grow-86977.html.

"Our Products: The Seaweed Company: Capturing the Value of Seaweed." Our Products | The Seaweed Company |Capturing the Value of Seaweed, www.theseaweedcompany.com/brand-products.

7. REFERENCES

Reijnders, R. (2022). Sealutions: Looking At Seaweed-Based Sustainable Building Materials in
the Netherlands. Delft University of Technology.

Reynolds, Emily. Japan's Clay Walls: A Glimpse into Their Tradition of Plastering. Peace Street Publications, 2009.

Sauerwein, M. (2020). Additive Manufacturing for Design in a Circular Economy. Delft University of Technology. https://doi.org/10.4233/uuid:1ffe3bd6-9592-40be-9a2a-7830778db093

"Seaweed Bungalows: Unique ECOLOGICAL Houses On JIAODONG PENINSULA."
Chinadaily.com.cn, 2020,
www.chinadaily.com.cn/a/202007/29/WS5f4868e-2a310675eafc56160.html.

"Seaweed Harvesting in the Netherlands i Ask the Expert." FoodUnfolded, www.foodunfolded.com/article/seaweed-harvesting-in-the-netherlands-i-ask-the-expert.

"Shikkui: Japanese Lime Plaster." The Year of Mud, 15 Aug. 2019, theyearofmud.com/2019/03/20/shikkui-lime-plaster/.

SP2 Life. "Anemia & Iron Deficiency - SP2 Spirulina." SP2 Life, sp2life.com/pages/anemia.

Vadstrup, Søren. "Hvidtning Af Lofter Med Mosfarve." Center for Bygningsbevaring i Raadvaad, Center for Bygningsbevaring i Raadvaad, Jan. 2010, https://www.bygningsbevaring.dk/uploads/files/anvisninger/14-ANVISN_Mosfarve.pdf.

"Veelgesteldevragen." Zeewaar, www.zeewaar.nl/nl/veel-gestelde-vragen.

Wan Mohammad, Wan Ahmad, et al. "A Review on Seashells Ash as Partial Cement Replacement." IOP Conference Series: Materials Science and Engineering, vol. 271, 2017, p. 012059., https://doi.org/10.1088/1757-899x/271/1/012059.

"What Is Shikkui Plaster?" SHIKKUI Royal Japanese Plasters, shikkui.net/shikkui-plaster/what-is-shikkui-plaster.html.

Seaweed Bungalows, 2019, www.chinatoday.com.cn/ctenglish/2018/cs/201911/t20191115_800185172.html.