The Seaweed Archives

A material study of seaweed as a building material and its implementation on two buildings on North Koster, Sweden.

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CHALMERS
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Thank you

Family & Friends

Jonas Lundberg
Jonas Runberger
Kengo Skorick
Jan Möller
Britt-Lisa Landahls fond

Abstract

At the beginning of April 2022, Sweden had already depleted its annual budget of the earth's resources (Global Footprint Network, 2022). The current climate and biodiversity crisis brings new challenges to architects as thirty percent of the global energy-related carbon emissions are produced by the building industry (Basyigit et al., 2021). Facing these challenges, the need for environmentally friendly and sustainable building materials has increased significantly.

This master thesis aims to offer an alternative to current conventional materials and move from carbon emission to carbon storage by focusing on an abundant, underutilized and, if harvested right, highly sustainable material: Seaweed. Seaweed, or macroalgae, is easy to grow and abundant along the Swedish coastline. It requires no land, fertilizers or fresh water and grows about thirty times faster than land-based plants. Marine plants (mainly eelgrass) have been used as a building material in the past as insulation and roofing material, and has been proven to be efficient and durable. Its natural resistance to mould and fire has allowed the material to be preserved for centuries (Widera, 2014). Although there are a few new examples of seaweed being used in architecture and design, it is still a quite underutilized material within this field.

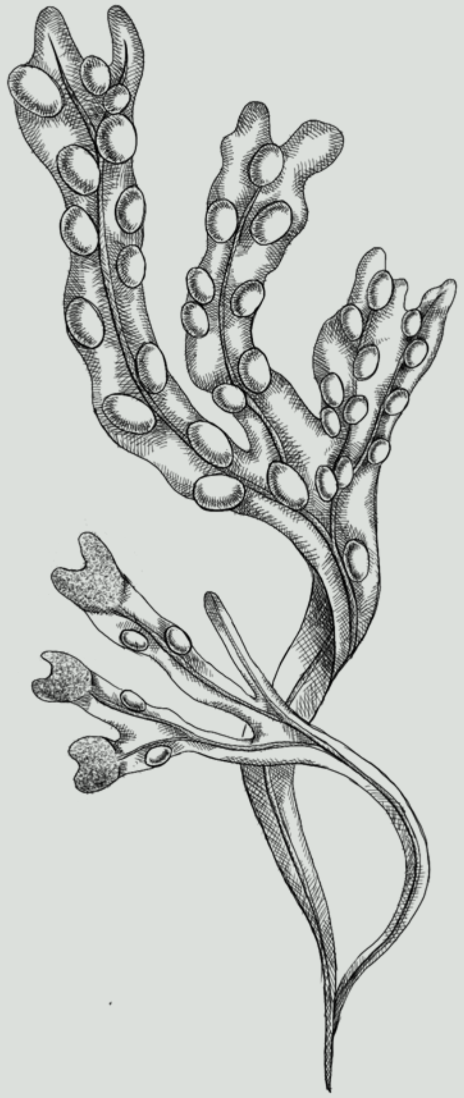
This master thesis highlights the versatility of seaweed and explores its potential use as a building material through material experiments and reference studies. As a part of this thesis, real architectural elements are proposed and tested in relation to different aspects like tactility, visual appearance and water resistance. The material experiments include bioplastics, bricks, panels and seaweed shingles serving as both interior and exterior materials. Material findings are applied to the design proposal of two buildings on the Swedish island North Koster. This site is surrounded by Kosterhavet National park, the first national marine park in Sweden and home to the most diverse marine life in the country.

One of the proposed buildings contains a café and exhibition space displaying the versatility of seaweed in architecture and design. The second built structure is a floating sauna platform that can be reached by foot or kayak.

KEYWORDS

seaweed, algae, material studies, koster islands, sustainable materials

Content



Fucus vesiculosus

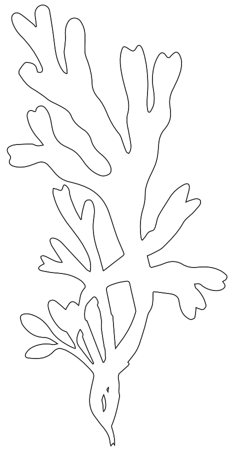
INTRODUCTION

Problem Statement

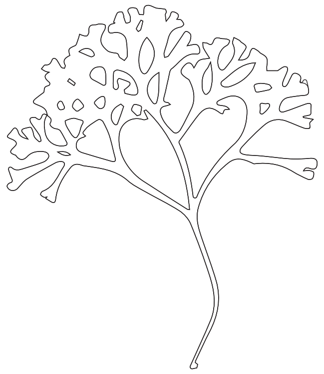
Why do we need better materials?

Increase in waste production, harmful carbon emissions, scarce resources and climate change are all extremely urgent issues that humanity is facing now. All of these issues are also very much influenced by the building industry as nearly half of the resource use is connected to the built environment (Brownell, 2020). Moreover, buildings are estimated to consume around 40% of energy and produce 36% of total CO_2 emissions in European Union. Within these numbers around 10-20% of the energy consumption is created by the production and utilization of building materials (Basyigit et al., 2021). Finally, concrete is currently the second most consumed material in the world (only after water) (Gagg, 2014) and in the same time it is responsible for 5% of total CO_2 emissions. Taking all of this data into consideration makes it is clear that there is a real need for change in the building industry. Architects should feel responsible for providing solutions that could reduce the impact of buildings on the environment. A very effective way to do that is to choose more environmentally-friendly materials in our projects. To take it one step further is to look for entirely new alternatives to current building materials. This urges to look into completely new material characteristics than before. When testing materials, what is usually taken into consideration are engineering attributes and aesthetic qualities. Sustainable materials on the other hand should also aim to reduce the usage of energy, minimize the waste production and reduce the CO_2 emissions throughout the whole life cycle of the building (Basyigit et al., 2021).

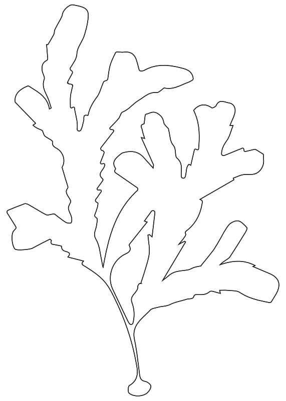
These new aspects create new challenges that architects and engineers will have to face. However, in a time of climate crisis and resource depletion they have to be acknowledged and addressed as early as possible. The aim of this thesis is to respond to these challenges and propose one of the solutions that could bring us closer to reaching the sustainability goals.



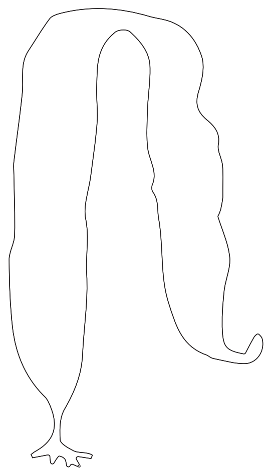
BLADDERWRACK
Fucus vesiculosus, blåstång (swe)



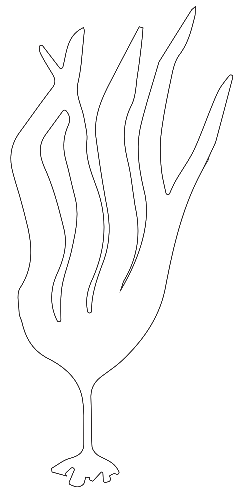
IRISH MOSS
Chondrus crispus, karragenalg (swe)



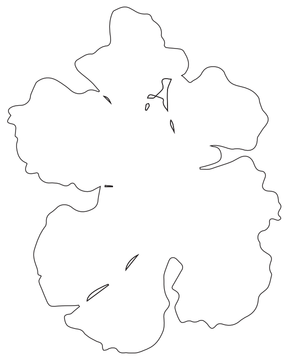
SAW WRACK
Fucus serratus, sågtång (swe)



SUGAR KELP
Saccharina Latissima, kombu, sockertång (swe)

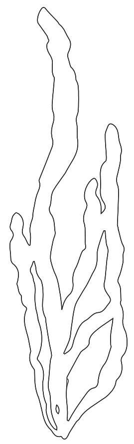


KELP
Laminaria Digitata, kombu, fingertång (swe)

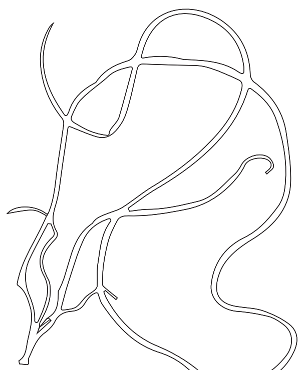


SEA LETTUCE
Ulva lactuca/fenestrata, havssallat (swe)

KNOTTED WRACK
Ascophyllum nodosum, egg wrack, knöltång (swe)



GUTWEED
Ulva intestinalis, green nori, rörhinna (swe)



BOOTLACE WEED
Chorda filum, närjtång, sudare (swe)

Material Choice

Why seaweed?

To many, seaweed may not seem like an obvious choice for an architectural material. However, there are multiple reasons as to why it is considered a great resource. It is non-toxic and its high salt content preserves the material and acts as a natural flame-retardant, all good properties for building materials. The life expectancy of seagrass as a building material has been estimated to be at least 150 years (Widera, 2014).

Seaweed can also grow thirty times faster than land based plants and does not require added fertilizers, land or freshwater. Instead, it relies solely on sunlight and the water, carbon dioxide and nutrients from the sea. By absorbing carbon dioxide from the ocean waters seaweeds can actually help fight climate change (Flannery, 2017). Large-scale seaweed cultivation, if done properly, can be a solution to mitigating the coastal eutrophication problem and improve water quality and local biodiversity. As seaweed grows, it binds to carbon dioxide molecules in the ocean and produces oxygen, essentially lowering the acidity of the ocean (Fei, 2004).

Seaweed, and algae in general, has long been used in coastal regions as a food source, fertilizer, energy source and for a variety of industrial applications. In Asia, in particular Japan, China and Korea, seaweed cultivation is a major industry. It is estimated that about 12 million tonnes of seaweed is grown and harvested every year from which three-quarters comes from China (Flannery, 2017). Europe's interest in seaweed cultivation has also grown in the past decade with the aim of creating a sustainable and local food source.

What if seaweed could also be grown for the purpose of creating sustainable building materials? During its growth, the macroalgae would create a natural habitat for seacreatures while absorbing carbon dioxide from the ocean and when harvested the seaweed biomass could be turned into buildings.

Thesis Framework

Aim

This thesis aims to explore the potential of seaweed in an architectural context. It studies the material's historical use and its modern design implementations and performs material experiments to guide the design of two buildings on North Koster, Sweden.

Thesis Question

- How can seaweed be introduced as an architectural element?
- What aesthetic and technical qualities of seaweed can be used as an input in an architectural design process?
- What is the potential of seaweed in the future of architecture and building construction?

Scope and Delimitations

The main focus of the thesis lies on exploring the potential of seaweed as a building material. Apart from investigating macroalgae, the thesis also includes studies on microalgae and seagrasses. The thesis's approach on the material investigations is mainly from an aesthetic point of view and the durability of the material.

The material's structural features are briefly investigated for a better understanding of the material, but are not thoroughly tested for strength or water resistance. The material sample evaluations are based on estimations and personal opinions, not definite calculations or tests. In the building design, the use of a stronger load-bearing seacrete (concrete) is assumed based on literary research instead of personally conducted experiments.

The two building proposals are meant to be seen as experimental buildings showcasing possible implementations of the materials created during the material investigations. The economical viability or building regulations on the site have not been investigated.

Reading Instructions

The main thesis booklet includes a curated version of the material experiments. For more information about all the material experiments, see *Appendix I: Material Experiments*.

Method

The work presented in this thesis has been created through research-based design. The thesis is based on literature studies, historical references, material research, material experimentations and study visits. This thorough research became a starting point for a design implementation where all the previous findings are analyzed and implemented in a building proposal. Material explorations and literature studies were performed at the beginning of the process after which the design proposal was developed and continued parallel to further investigations.

Literature Studies

Articles, books and publications within the subject of microalgae, macroalgae and seagrass have been studied to understand the characteristics and delimitations of the materials. Literature on the topic of building materials and sustainability in the building industry was also analyzed to define the problem statement.

Historical References

History of usage of the material on a global scale was investigated and analyzed through articles and publications. This research explored what the material has been used for in the past and what is the potential of its future use.

Material Research

Contemporary works of fashion and interior designers, artists and architects have been studied to investigate what aesthetic and technical qualities the material has. Apart from that the methods and material recipes were analyzed and tried out to create a base for new material explorations.

Material Experimentations

At the start of the thesis all the derivatives of seaweed were bought and seaweed was harvested from a local source. Using these ingredients various material experiments were made where different qualities of materials were investigated. Most of the experiments were conducted in a self-made study space but there was also one experiment performed in a lab with the use of hydraulic heat press. The recipes used for the first experiments were based on the previously done material research. Later on they were altered, adjusted and perfected to fit a desired outcome.

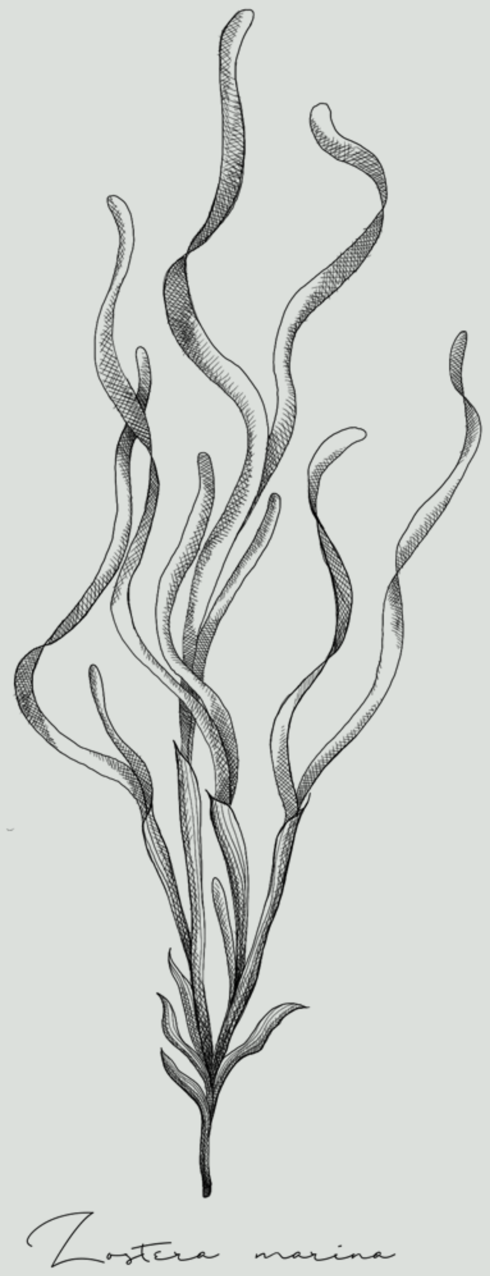
Study Visit

A study visit was done at the site of the design proposal. The aim of the visit was to investigate the local conditions of the site as well as to explore the local wildlife including the analysis of seaweed species that can be found on the site.

Program

The design proposal is made up of two building projects. The first structure is an exhibition hall with a cafe. In this building two seaweed materials are implemented. The first one is seacrete (concrete made out of seaweed and seashells) made into prefabricated blocks that form the main structure of the building. The second one is bioplastic welded into inflatable pieces that form a colorful corridor on the top floor of the building.

The second building is a floating sauna placed on a wooden deck. Here the main focus is put on facade cladding made from kelp leather that forms seaweed shingles. The platform is surrounded by a bioplastic stretched around a frame that acts as a wind barrier.



BACKGROUND

Algaes and Seagrasses

Marine plants, like land-based plants, rely on photosynthesis to live. The two main types of marine plants are algae and seagrass. Among algae it is possible to differentiate microalgae and macroalgae, commenly known as seaweed. This thesis focuses on macroalgae as a material, but also includes microalgae and seagrass. Microalgaes are in this case uses for colouring material samples and seagrass is used for insulation in the buildings.

Microalgae

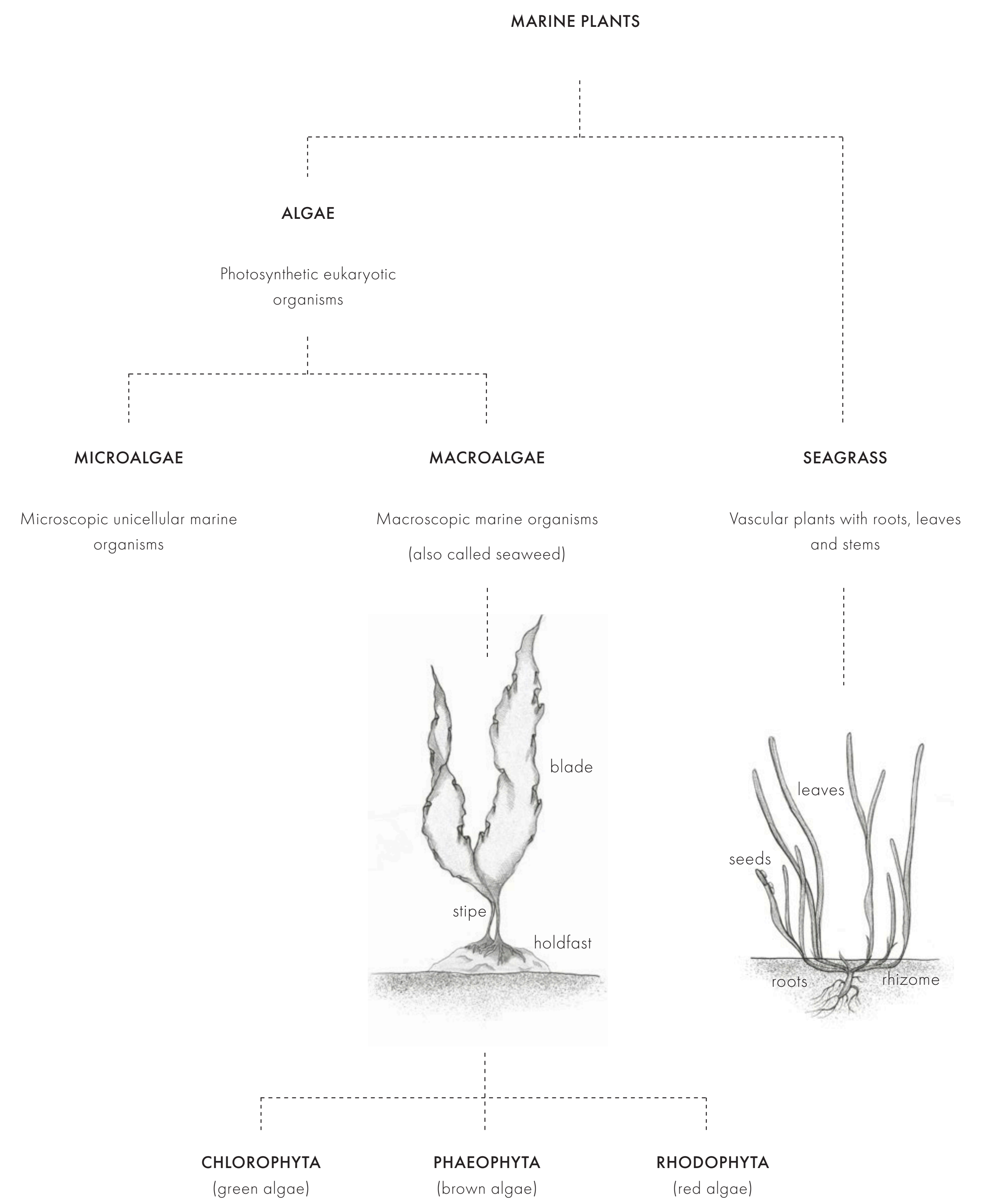
Microalgae are unicellular phytoplankton and an integral part of the earths ecosystem. Even though these microscopic algae only make up about one percent of the global plant biomass, they are responsible for approximately fifty percent of the production of atmospheric oxygen on earth. They also form the base of the food chain giving energy to essentially all above them. Microalgae has about 50,000 documented species, including spirulina, chlorella and diatoms, but an estimated number of species of around 200,000-800,000 (Barsanti and Gualtieri, 2014).

Macroalgae

Macroalgae are macroscopic, multicellular algae and are more commonly called seaweed. Seaweeds use diffusion to extract nutrients from water and reproduce with spores. Within this group seaweeds can be typically classified into three groups: Green seaweeds known as Chlorophyta including pigments of chlorophyll a and b, brown seaweed (Phaeophyta) containing pigments of chlorophyll a and c as well as fucoxanthin and finally red seaweed (Rhodophyta) with pigments of phycocyanin and phycoerythrin (Tiwari, et al., 2015). The reason for different pigments in each of these groups is the light absorption. In the same way as trees, seaweed uses photosynthesis to convert the energy coming from the sun into chemical energy. Sunlight passes through water and longer wavelengths (like red, orange and yellow) are filtered out first, which means that in the end the only light that remains is a faint blue-green light. It is not possible for this kind of light to be absorbed by chlorophyll which is why we can usually find green and brown seaweed only near the shoreline (Graham, et al., 2009).

Seagrass

Seagrass is often confused with seaweed but in fact there are very clear differences between the two. Seagrasses are vascular plants with roots, leaves and stems. They extract nutrients from the environment by using roots, rhizomes and leaves and they have separate sexes for purpose of reproducing. Seagrasses evolved from land plants while algae is a completely different group of organisms. Seagrasses are also not as diverse as macroalgae. Only 55 species of seagrass can be differentiated, the most common species being zostera marina, also known as eelgrass (Florida Fish And Wildlife Conservation Commission, 2019).



Algae Derivatives

As mentioned before, apart from different species of seaweed in this project derivatives of macroalgae and microalgae were also used. The three main seaweed extract are the following hydrocolloids: agar, alginates, and carrageenans. All of them are extracted from different species of brown and red macroalgae. A hydrocolloid is a substance with very large molecules that can dissolve in water and create a thickened solution (Barsanti and Gualtieri, 2014). In the following paragraph all of the derivatives used in the project are described.

Agar

Agar is a substance extracted from some species the red algae. High-quality agar is mainly extracted from a species called *Gelidium*. Thirtyfive percent of the world's agar production actually comes from this particular type of seaweed. When it comes to lower quality agar it is usually extracted from *Gracilaria* and *Hypnea* species (Barsanti and Gualtieri, 2014). Agar is commonly used in laboratory preparation of growth media, molecular biology and food processing (Graham, et al., 2009) as a vegan alternative for gelatine.

Alginate

Alginates are components of cell walls of brown algae. Alginates can be found in almost all types of seaweed but they are usually extracted from kelps and wracks. When it comes to application, they are often made into fibers and used in textiles industry or used as medical dressing for wounds. Alginates are also used in printing, cosmetics and even in ice cream production (Barsanti and Gualtieri, 2014).

Carrageenan

This hydrocolloid comes in more than one form but all of them are extracted from different species of red algae. There is a harder and more brittle Carrageenan kappa, more flexible Carrageenan iota and non gelling Carrageenan lambda. In this project Carrageenan kappa was used which is obtained from red algae species *Kappaphycus alvarezii*. Carrageenan is used in production of some of the cosmetics and drugs. It is also added to toothpastes as a binder (Barsanti and Gualtieri, 2014).

Spirulina

This additive is a microalgae. Spirulina is a cyanobacterium collected from its natural environment or grown in ponds. In nature it can be found both in fresh- and marine waters. It has a very high protein-content and is easy to digest so it has been commonly used in food production (Graham, et al., 2009). It is also added to cosmetics to prevent skin aging (Barsanti and Gualtieri, 2014). In this project both green and blue spirulina was used as a color source.

Astaxanthin

Astaxanthin is a caretonoid extracted from *Haematococcus pluvialis* microalgae. It has a strong red color and it is used among other things as a food colorant. This derivative has also positive effects on human health such as being an antioxidant so it is also a subject of interest in pharmaceutical industry. In this project astaxanthin was used as a color source.

From left to right: agar, blue spirulina, green spirulina, astaxanthin

Seaweed Bungalows in China

Jiaodong Peninsula, Shandong Province, China
200 BC -1900 AD

These houses have a long history and are mainly found in the coastal areas of Weihai, Yantai and Qingdao in the Jiaodong Peninsula of east China's Shandong Province. They can be traced back to the Neolithic Age but where not used for folk houses then. After the Qin and Han dynasties (221 BC - AD 220) they became more common and during the Ming and Qing dynasties (1368-1911) they were widely adopted as the coastal population increased significantly (Zhang et al., 2011).

The buildings consist of thick walls made of mud, sand, grass- and oystershell powder and are covered in local rocks. The roofs are covered in a thick matt of seagrass, a process that is completed by hand and requires skill. Seagrass is harvested and sorted depending on colour, shape and size and then straightened and tied up one layer at a time. The roof consists of alternating layers of seagrass and wooden frame structures. This wooden frame helps trap the air between the layers and add extra insulation, keeping the houses warm during the winter and cool during the summer. The roofs are also matted to create a thicker mat on the top, thereby increasing the slope of the roof for easier drainage of water. The amount of seagrass needed to build one roof can exceed 5,000 kilograms. Sometimes the roofs are covered in fishingnets to prevent harsh winds from blowing the seagrass of the roof (Zhang et al., 2011).

Seaweed bungalows are still widely represented in this region and are a great example of vernacular architecture, and a symbol for the local culture and history. The picture on the right shows the Seaweed Bay Health Resort by Greyspace Architecture Design Studio, the renovation of a number of old seaweed bungalows.

Photo credit: Hao Chen (2021)

Seaweed Houses on Læsø

Læsø, Denmark
1650 -1870

A one hour and forty minute boat ride outside of Fredrikshamn lies the Danish Island Læsø. During the 17th century this island was well known for its salt production. The thriving salt industry led to the deforestation of the island as trees were chopped down to provide firewood for heating the salt barrels. The islanders were forced to look for alternative building material and the excess of eelgrass (zostera marina) led to their use in the buildings. These weird-looking houses date back to the 1650's and are a great example of vernacular architecture. The eelgrass roofs are special since they have a unique construction made purposefully to work with the material (Jensen, 2012).

The women were responsible for harvesting the seagrass and building the seaweed houses and were called "vaskerpiger" (Jensen, 2012). The process of building was a group effort and up to 100 people were involved in building during the day. The men were often away at sea and would collect wood from shipwrecks to use as building materials. According to Jensen (2014) seaweed houses also existed in Halland in Sweden around this time but little information can be found about these houses.

The last fully thatched roof was completed in the 1870's, since then roofs have only been repaired. In the 1930's a wasting disease destroyed around 90% of eelgrass crops in North America and Europe. During this time there were around 230 seaweed houses on Læsø. This number dropped to 90 in the 1970's and nowadays there are only 19 houses standing.

Photo credit: Søuld (2021)

Seagrass Insulation

mainly 17th -20th century

In the United States, the use of seagrass dates back to the 17th century when settlers used eelgrass as insulating materials and bedstuffing. In 1891 Samuel Cabot Inc. based in Boston acquired a patent for Cabot's Quilt, thermal and sound insulation made of stitched layers of dried eelgrass inbetween heavy kraft paper. The eelgrass was gathered by farmers and fisherman in july-october when it did not interfere with fishing- and farming season (Moe, 2014). Cabot's Quilt supplied their insulation material to the United States, Canada, Asutralia, New Zealand, Sweden, Finland, Holland and Argentine Republic (Cabot, 1928). Guildfords Limited, a company based in Nova Scotia, Canada also produced eelgrass insulation around this time. The bussinesses expanded greatly and started importing eelgrass from other countries. Titanic had a shipment of dutch eelgrass on board (Nienhuis, 2008).

Some well known buildings with eelgrass insulation are Rockefeller center and Radio City Music Hall in New York City due to its great acoustic properties (Wylle-Echeverria & Cox, 1999). The eelgrass insulation material is also pest-resistant due to its high silicate content, mold resistant, requires a low energy consumption during production, and can be reused, for example as a plant substrate.

In the 1930's, with the global eelgrass disease, the production of eelgrass insulation was not able to continue. Guildfords Limited tried to restart production in the 1950's, but failed to commercialize production as there were now other insulating materials such as fiberglass and other synthetic fiber insulation on the market.

Seagrass and seaweed on the beach

Modern Seaweed House

Architect: Vandkunsten Architects
Client: Realdania Byg
Site: Læsø, Denmark
Built: 2013

Realdania Byg Foundation acquired a piece of land on Læsø in between a modern summer house design by Danish architect Hanne Kjærholm and a traditional seaweed house from 1865. They announced a competition for the design of a small summer house that would fit in with the traditional seaweed house as well as the modern summer house. Vandkunsten won this competition with their proposal of the Modern Seaweed House which builds upon the centuries-old building technique of the eelgrass roofs on Læsø. Seaweed, or in this case actually seagrass, reproduces itself in the ocean and drifts up on land without human effort and is dried in the sun on fields nearby. It also stores carbon dioxide, is non-toxic, fireproof and has a life expectancy of more than 150 years. The LCA (life cycle analysis) actually show that the building has a negative carbon footprint, meaning that the eelgrass binds to more carbon dioxide than is emitted from the transportation and building process (Dezeen, 2013).

The Modern Seaweed House, with its wooden structure, incorporates eelgrass in three different ways: as insulation, interior padded cladding and exterior cladding. This house was meant as an experiment of the possibilities of using eelgrass in modern architecture, and not as a social experiment. The house has a simple structure with a pitched roof but stands out due to its unique use of the material.

The eelgrass is bound into nets to be used for the facade and roof cladding. Loose eelgrass is used in the walls, floors and roof and acts as a sustainable and effective insulator and contributes to a good interior climate due to its ability to absorb and release moisture. The use of eelgrass in the padded interior cladding also adds good acoustic qualities (Dezeen, 2013).

Photo credit: Helene Høyer Mikkelsen (2013)

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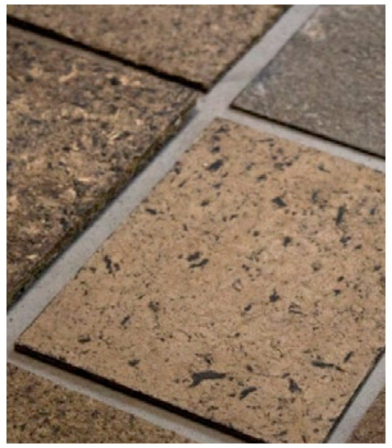

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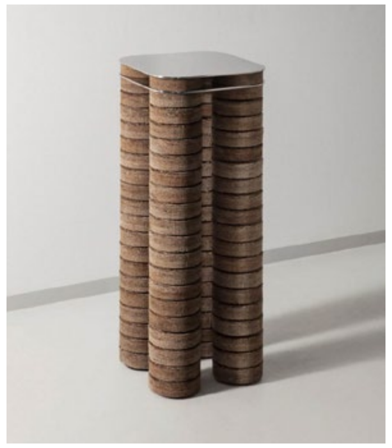

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11

12

Design References

1. Oki Naganode (Lohmann, 2013)
2. Terroir Project (Schmidt, 2015)
3. Terroir Project (Schmidt, 2015)
4. Algae Lab (Antoine Raab, 2017)
5. SeaWood (BlueBlocks, 2021)
6. Kathryn Larsen (Larsen, 2018)
7. Algae Sequins (Raff, 2019)
8. Sea Me (Poort, 2014)
9. Momentum (Boersma, 2021)
10. Bioplastic Raincoat (McCurdy, 2019)
11. Bioplastic dress (One X One, 2021)
12. Seaweed Girl clothing line (Linington, 2019)

Although the use of seaweed is still very uncommon in modern architecture, in the design world seaweed has had a spike in popularity in the last decade. The material is used in interior design, art installations, fashion, furniture design and packaging. To the left, some examples of designers or projects are showed.

Julia Lohmann, a german-born designer, researcher and founder of the Department of Seaweed, investigates the potential of seaweed as a design material. In her installation 'Oki Naganode' at the Victoria & Albert Museum in 2013 she showcased flexible seaweed stretched over a cane framework. Julia has also created laser-cut kelp lampshades (Dezeen, 2020).

The Terroir Project by Jonas Edvard and Nikolaj Steenfatt has resulted in a chair and pendant lamps made from only seaweed and paper. By drying seaweed, grinding it into a powder and cooking it for several hours, a natural glue is created from the alginate in the brown algae which has a strong adhesive strength (Dezeen, 2015).

Algae Lab is a collaboration between dutch designers Eric Klarenbeek and Maartje Dros and atelier LUMA. They developed a method of processing algae into a filament that can be used to 3D print objects with (Dezeen, 2017).

Søuld is a Danish company that manufactures acoustic mats made from eelgrass. In 2021, designer and architect David Thulstrup created the exhibiton MOMENTUM in which he exhibited a furniture collection from Søuld's eelgrass mats (Søuld, n.d.).

Kathryn Larsen has constructed prefabricated eelgrass thatched panels inspired by the traditional roof thatching technique on Læsø. She also continues investigating the possiblities of seaweed within the building industry (Studio Kathryn Larsen, n.d.).

Seaweed can also be used to create yarn, as can be seen in Nienke Hoogvliet's design of the Sea Me rug (Dezeen, 2014). Seaweed and algae have also been used within fashion as is the case with the bioplastic raincoat designed by Charlotte McCurdy and the bioplastic dress that was the result of a collaboration between her and Phillip Lim (Dezeen, 2021). Jasmine Linington has also designed clothes with kelp sequins.

Ascophyllum nodosum

MATERIAL INVESTIGATIONS

This chapter includes the material investigations which are divided up into three main categories; Bioplastics, Seacrete and Kelp Leather. More information about each material expriment can be found in Appendix I: Material Experiments.

The Lab

Setup and hanging kelp

Process of creating bioplastic

Bioplastics

Petrochemical plastics have become a big part of our daily lives and can be found in almost all the objects of everyday use as well as building materials. Because of the fact that these plastics are nonbiodegradable and are not being properly disposed, the plastic pollution has become a world scale problem leading to death of many ecosystems and millions of living creatures. As an alternative to these not environmentally friendly materials there has been a growing interest in biodegradable microbial bioplastics. According to reports many different microorganisms can be a source of these bioplastics (Kuddus, M. and Roohi, 2021). Among these organisms there is seaweed and algae. In bioplastic production the most commonly used algae derivatives are agar, alginate and carrageenan. These are usually being used to create films and thin plastic sheets. Seaweed bioplastics are able to biodegrade in only four to six weeks and they will not degrade into microplastics in a way that petrochemical plastics do (C. Limet et al., 2021).

In this part of the project the possibilities of microbial bioplastics made from seaweed were explored to perform as building materials . The process began by researching already existing examples of algae-based plastic products and recipes. The first experiments were based on the recipes coming mainly from two sources: "How to make sustainable plastics" video (Science Gallery Melbourne, 2020) and "Bioplastic Cookbook" (Fab Textiles, 2018). Basing on these two various different ratios of each of the ingredients were tried out which allowed us to achieve different results each time. One of the various projects that inspired the process was SEAmpathy by Daniel Elkayam. In the first experiments the focus was put on creating similar texture and thickness as presented by the artist. Another design used as an inpiration for these samples was SeeTang Collection project by Jana Aimée that focused on creating sustainable packaging from seaweed and Carolyn Raff Circular Oceans fashion project looking into experimentation with sequins made from seaweed film. All of this research resulted in the set of different samples that we present on the pages below.

The first batch of samples was made using three main ingredients: water, agar and glycerine. The work was focused on experimenting with different ratios of each of the ingredient and different coloring additives- green spirulina, blue spirulina and astaxanthin. To the right, one of the experiments is described in detail.

Agar Bioplastic

Experiment No. 005

INGREDIENTS

150ml water / 3g agar / 3ml glycerine / 0.5g spirulina

PROCESS

Water was poured into a pot and agar was added in it directly. Once the mixture was brought to boil the glycerine was added to it. The heat was then lowered and the substance was left to simmer for around 5 minutes. During this time the water evaporates from the mixture so it becomes thicker and more gel like. After that happened the spirulina was added in the mix and the pot was shook around for a minute to let it blend in just a little. After that the mixture was poured into a metal mold and left to cool down for couple of hours. Later the film was taken out of the mold and hung up with pegs to dry fully. The whole process of drying took around 2 days.

OBSERVATIONS

It was observed that adding the spirulina at the end of the cooking process and shaking the pot just to let it mix a little creates a good looking effect of speckles of color in the material. This sample dried pretty fast and was not as wrinkled as the previous ones. The reason for that could be the fact that a thinner layer of the substance was poured and the material was kept in a wooden frame while drying. As in the previous tests it was clearly noticeable that the agar bioplastic material undergoes a quite significant shrinkage both in thickens and in width/length.

After the agar experiments more bioplastic samples were made. The hydrocolloid was switched from agar to carrageenan to compare the results. Again different pigments and additives (like flakes and powders from ground seaweed) were incorporated.

Carrageenan Bioplastic

Experiment No. 015

INGREDIENTS

150ml water / 3g carrageenan / 3ml glycerine / 1g kelp flakes

PROCESS

Water was poured into the pot and carrageenan was added in it directly. Once the mixture was brought to boil the glycerine was added to it. The heat was then lowered and the substance was left to simmer for around 5 minutes so the water could evaporate and the mixture could become thicker. After that kelp flakes were added to the pot. The mixture was stirred so the flakes could mix with the carrageenan substance. It was then boiled for 2 more minutes. Next step was to pour in the mixture into a metal mold. It was then left to cool down for couple of hours. Next the plastic was lifted up from the mold to make sure it does not stick. Finally it was left in a dehydrator on a metal plate for 6 hours to dry fully.

OBSERVATIONS

It was observed that comparing to agar samples the carrageenan plastic turned out to be less see- through. What is more the agar plastic has a glossy finish while carrageenan sample turned out more matte (paper like texture). It was noticed that kelp flakes ground to around 2 mm size create interesting terrazzo like texture on the sample. The sample dried really fast in the dehydrator. Because it was placed on a metal plate it also dried quite flat and not wrinkled. As in the previous tests it was clearly noticeable that in the same way as agar bioplastic carrageenan material undergoes a quite significant shrinkage both in thickens and in width/length.

A selection of the bioplastic material experiments

Discussion

Ratios

The ratios influence the final result of the sample. If more glycerine is added the material becomes more flexible, samples with no glycerine are very brittle and hard. The ratios of colour additives make a big difference as well. E.g. when a pinch of green spirulina is added the colour becomes light green, when a table spoon is added the colour is almost black.

Shrinkage and Deformation

The material shrinks significantly while drying. The shrinkage can be observed mostly when it comes to thickness as the sample can shrink even up until around 60%. This creates a limitation to how thick the material can be. The samples can also wrinkle a lot while drying. This can be controlled until some extend with how they are placed to dry. If a sample is placed on a flat non stick surface it is more likely to dry flat. Samples can be controlled with heat. Two sheets can be melted together, they can also be welded- heated together to form a seam.

Water Resistance

The material is not waterproof itself and needs to be additionally treated. Some tests were made to make the material waterproof using beeswax and the effects were positive, however making it fully waterproof requires further investigation.

Colours and Patterns

There are a lot of different techniques that allow to achieve different colours and patterns of the samples. Spirulina and astaxanthin depending on the way of mixing can create fully coloured sample, speckles effect or even a marbling effect. An interesting colourful pattern can be also achieved with usage of "vegan caviar" made from alginate and different colouring additives.
What is more seaweed blended into flakes creates a terrazzo effect that can vary in colour depending on the type of seaweed used. It has been observed that astaxanthin is prone to colour loss over time. The usage of this colour additive should be investigated further to prevent this issue.

Material Properties

- Biodegradable
- Water solvent, especially in warm water. Can be made waterproof with a wax.
- Flexible
- Quite strong with the right recipe
- Can be welded
- Can be inflated
- Large diversity with colours and patterns

Seacrete

Concrete is currently the most commonly used material in the building industry. It is versatile, cheap and easy to make so the demand for it is constantly growing. However, the great disadvantage of concrete is it's enormous carbon footprint. Around 8% of all the global emissions comes from the cement industry. During the process of production when limestone with clay is heated up, around 600 kilograms of CO2 is released into the atmosphere for every tonne of cement made. (Nature, 2021) All this data shows that there is a need for more sustainable building material with similar qualities that could compete with concrete. That is why we started to investigate on how to create biobased structures that could replace concrete blocks.

Hydrocolloids derived from algae have already been tested in cement- based materials and the results were proven to be promising. Carrageenan use in this kind of material has resulted in higher yield stress and plastic viscosity as well as better resistance to forced bleeding in comparison to a petrochemical-based admixture. (Boukhatem et al., 2021) What is more, there are many material experiments that show it is possible to create building blocks and panels with usage of algae. One of the projects that was used as a reference for these material investigations is "Terroir" by Jonas Edvard and Nikolaj Steenfatt. It focuses on developing a material made from seaweed and paper to use in furniture pieces. The glue in the mixture is derived from cooked brown seaweed. A second inspiration was a project by HuisVeendam "Biolaminates" where starch based glue is combined with different ingredients like mussels, seaweed or grass to create a biobased material. The results are then implemented in different interior design pieces. Another example that was investigated is "Calcareous" by Carolina Pacheco that looks into possibilities of using seashells and alginate mix as a building and 3D printing material.

Examining these and many more projects and research articles was a great help in understanding how to create a material with a desired shape and thickness that could be implemented as a part of a building structure. This was then put into practice in the experiments described below.

The next batch of experiments were experiments focusing on creating a material with thickness. After couple of failed tries to press only seaweed it was clear that to get a successful sample the experiments must be made with different additives. One type of the materials used were seashells.

Seaweed + Oysters

Experiment No. 112

INGREDIENTS

40g oyster shells powder / 10g seaweed / 40ml alginate solution (2,5%)

PROCESS

First the oyster shells were put in a cloth and crushed with a hammer. The crashed pieces were put through a sieve to get just the fine particles of the shells. This process was continued until 40 g of seashells powder was made. Later the alginate solution was made by mixing alginate with water and letting it sit for 24 hours. The next day the shell powder was mixed with alginate solution and dried seaweed pieces. The mixture was then transfered into a wooden mold prepared in advance. The size of the mold used for this sample was 4 cm x10 cm. Next the mold with the sample was put inside the oven for 35° for around 2 hours. After that the piece was taken out of the mould and put back in the oven for 12 more hours.

OBSERVATIONS

The mixture prepared bound really well. The sample after fully drying in the oven turned out to be hard and pretty strong. It came out as a homogeneous solid piece which was a promising result. Adding the pieces of dried seaweed to the mixture resulted in interesting marble like pattern on the sample. The sample needed to be put in the oven to dry fully and the drying process was pretty slow. However drying didn't deform the sample as it happened before with some of our previous experiments.

Next section of experiments was focused on using recycled paper as an additive. The samples had different amounts of paper and seaweed in them as well as different types of paper were used. (eg. used tissues or used printing paper).

Seaweed + Paper

Experiment No. 109

INGREDIENTS

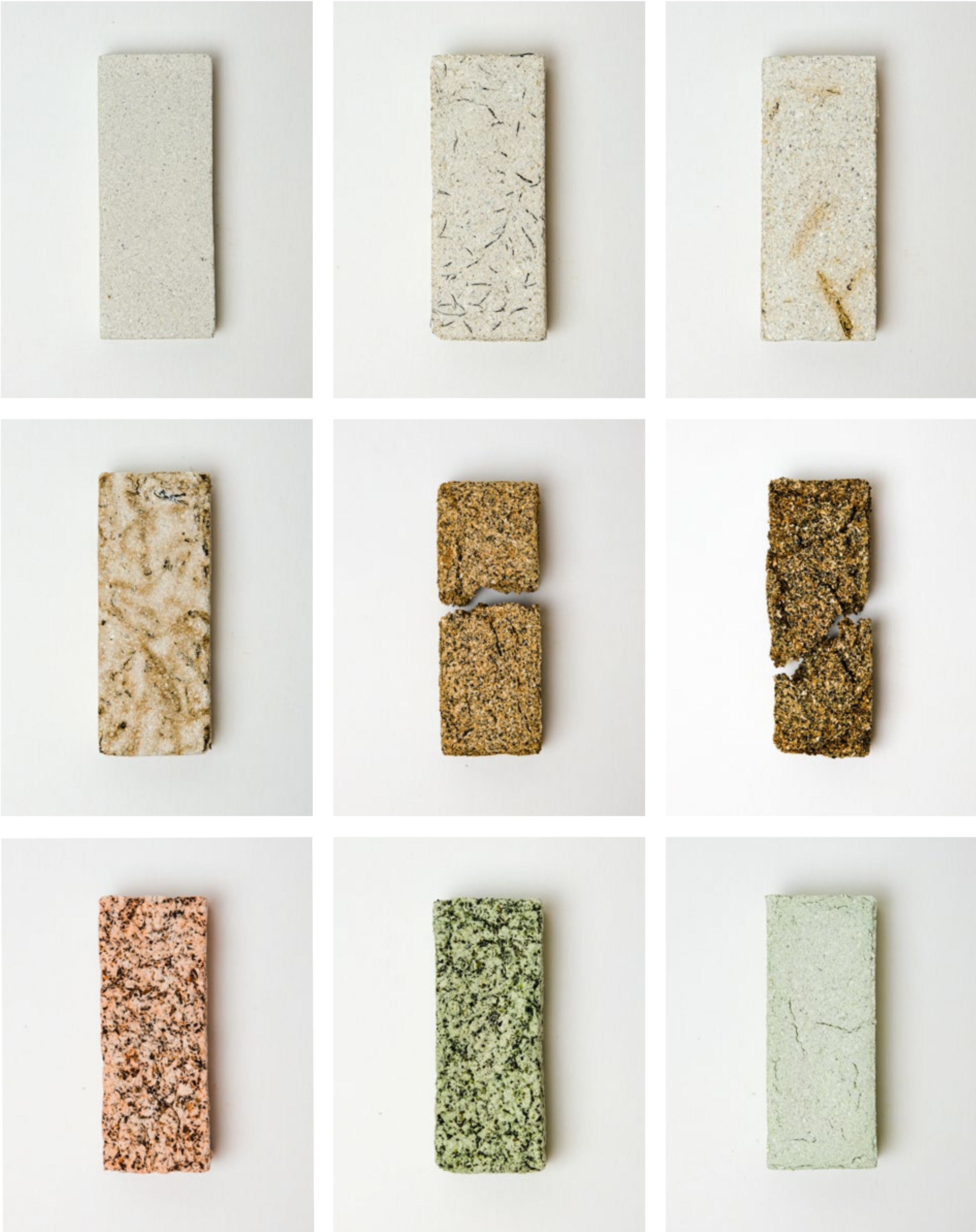
10g dried kelp powder / 10g recycled paper / 10ml alginate solution (2.5%) / 1g spirulina / water

PROCESS

First the recycled paper was collected and put it in a bucket of water to make it softer and easier to blend. In the same time the pieces of dried kelp were blended using a kitchen blender. Next step was to put the dried blended pieces of seaweed in some water and boil them. The seaweed was boiled for two hours and during this process the water was constantly added to it. In total around 500 ml of water was added. During that time the paper was also blended and boiled in water for around 1 hour. After that the excess water was drained off from the paper. Later on boiled seaweed was mixed with prepared paper additive. In the next step alginate solution was added to the mixture. (As in the previous experiment alginate solution was prepared the day before). Finally the green spirulina was added. Everything was then mixed and the excess water was drained again. The next step was to transfer the mixture into a mould. It was then pressed it in the mould to make sure the desired shape is achieved. The size of the mould used for this sample was 4 cm x10 cm. Next the mould with the sample was put inside into the oven for 35° for around 2 hours. After that the piece was taken out of the mould and put back in the oven for 12 more hours.

OBSERVATIONS

The mixture bound really well. The sample came out as a homogeneous solid piece. However, it turned out much lighter after fully drying. The same recipe was tried out with different color additives which resulted in different final effects.
The sample needed to be put in the oven to dry fully and the drying process again was quite long. The sample was not significantly deformed after drying but it became a little dented.



A selection of the seacrete material experiments

Discussion

Ratios

The material has been tested with various additives. The best results were achieved with usage of seashells and alginate. The best ratio is around an equal amount of seashells and alginate solution. Seaweed can be added to the mixture to create more diverse samples but there is some limitation to that as too much seaweed can cause the seacrete to not bind properly and crack.

Shrinkage and Deformation

Shrinkage was only observed in samples where the paper was the main ingredient. Seacrete samples do not shrink and can be easily moulded into desired shape.

Water Resistance

The material itself is not waterproof and needs to be additionally treated. Tests were made to make the samples water resistant with usage of calcium chloride, however additional tests are needed.

Colours and Patterns

The samples can be coloured with different colouring additives like spirulina but the amounts needed are bigger than when it comes to bioplastics because the colour partially fades while drying. Interesting colouring and different patterns can also be achieved by adding dried pieces of different species of seaweed.

Material Properties

- Water solvent, can be made water resistant with treatment
- Quite strong
- Easy to mould
- Many possibilities with colours and patterns

Kelp Leather

Exterior cladding can be made from various materials with different life expectancies and environmental impact. The most popular cladding materials are concrete, metal, glass and timber. (Brookes and Meijs, 2014) When searching for the most natural and unprocessed cladding one would probably choose timber, however variety of timber facade options is limited.
This material exploration aimed to create a natural, unprocessed material that could offer an alternative to the currently existing facade cladding options. During this investigation it was important to use a full potential of seaweed while processing it as little as possible.

Kelp leather has been already used in design and fashion before. It is known to be strong, versatile and when treated in a right way it can be very easy to shape in a desired way. What is more it possesses qualities that other materials lack for example it can change colour over time.

The main inspiration for this material research was the work of Julia Lohmann. This designer creates fashion and art pieces from seaweed. Her installation "Oki Naganode" made from seaweed showcases all the the qualities mentioned before. Another project that served as an inspiration for this investigation is "Seaweed Matters" a master thesis made by Jing-cai Liu where this Industrial Designer created different fashion pieces like shoes and bags out of kelp leather. Analysis of these and many more projects was then put into practice by performing the experiments described in this chapter.

Dried kelp

Kelp treated with glycerine

Seaweed + Glycerine

Experiment No. 203

INGREDIENTS

dried kombu kelp / glycerine

PROCESS

First the dried kelp was soaked in water for at least 20 minutes. Next when the kelp became completely flexible it was taken out of the water and any excess water was removed with a towel. Then about a tablespoon of glycerine was measured and spread out over the entire piece. The same was done on the other side. Finally the piece was left to dry between two paper towels for two days. After this time if some spots have hardened, some more water was sprayed on them and a second layer of glycerine was added on them as well. The process was contentiously repeated until the entire piece became flexible when dry.

OBSERVATIONS

White spots can appear on the kelp during the drying process, this is salt and can be removed by spraying some water and adding more glycerine on the spot again. This sample is quite flexible when dried. The center of the kelp is thicker however and therefore less flexible.

Discussion

Ratios

There is no set amount of glycerine that needs to be spread out on the kelp to make it flexible. The amount needed depends of the thickness of the piece and the size of it.

Deformation

If kelp is not treated in any way it will harden after drying and become brittle. Using additives keeps it flexible and allows to shape it in a desired way.

Colours

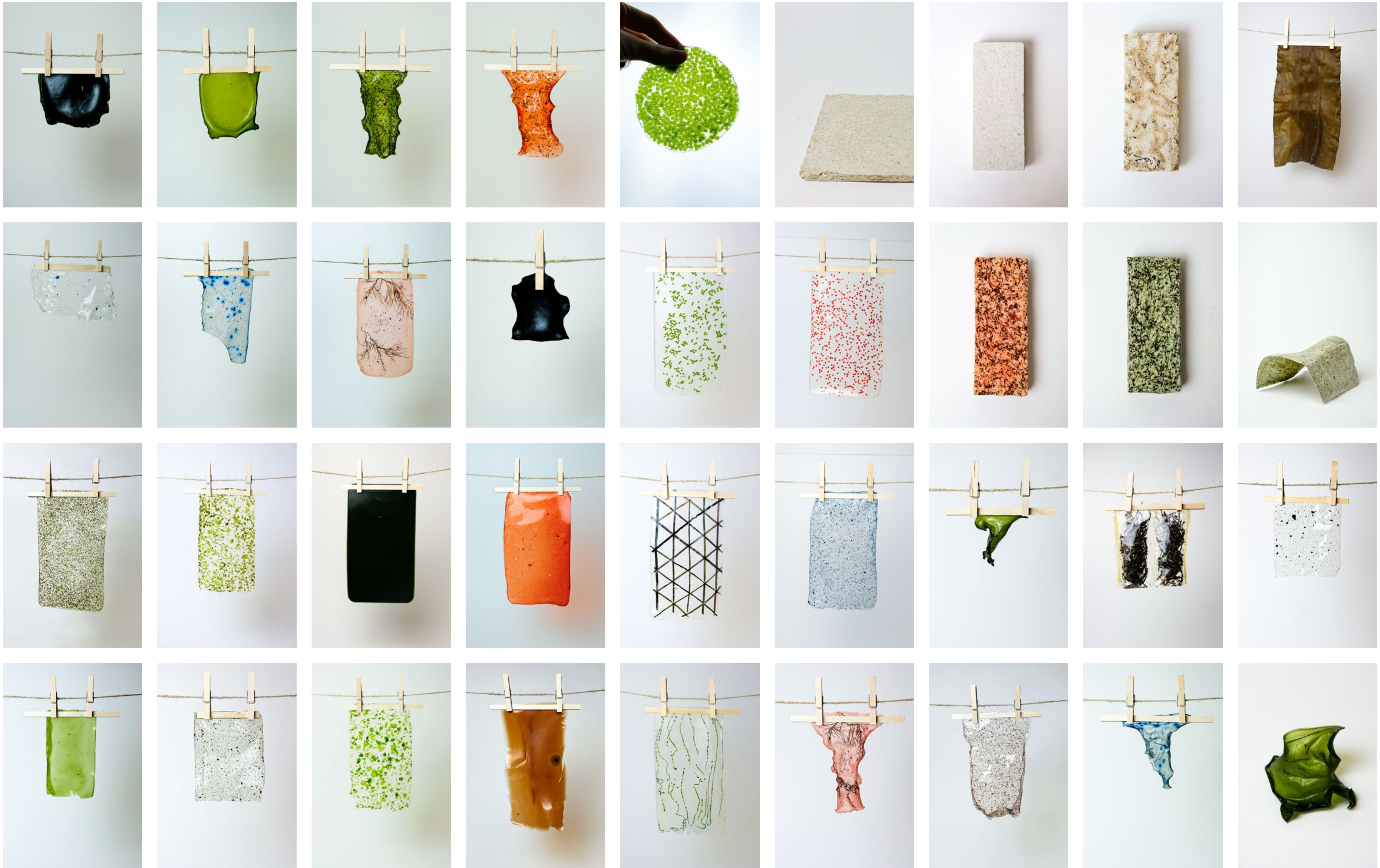
An interesting characteristic of kelp is that exposed to sun for a long time it changes colour. Originally brown kelp becomes light yellow colour after sun exposure. This means the material will change it's looks over time.

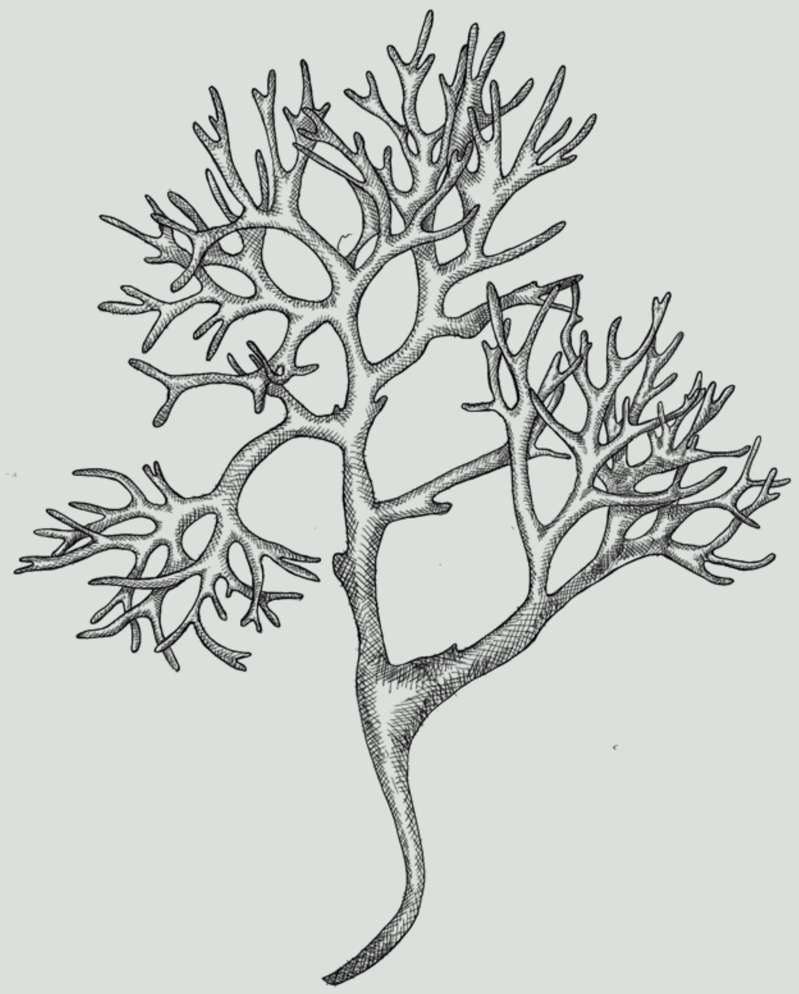
Water Resistance

To keep the kelp flexible after treating it with glycerine it needs to be waterproofed. Some tests were made using bees wax to achieve a water resistant kelp leather, however more tests are needed to get a fully functioning waterproof material.

Material Properties

- Biodegradable
- Can be made waterproof
- Strong material
- Easy to shape
- Changes colour over time.





Chondrus crispus

SITE

Kosterhavet National Park

Kosterhavet National Park, the first and so far only national marine park in Sweden, covers a large part of the ocean surrounding the Koster Islands as well as part of South Koster. It covers an area of 400 square kilometers and is home to the most diverse marine life in Sweden. 6000 individual marine species have been documented of which 300 species have not been found anywhere else in Sweden. Under the surface, there are large kelp forests and seagrass beds. One of the reasons for this high biodiversity is the one kilometer wide Koster trench which stretches between the Koster islands and the mainland with a depth of up to 247 meters (Sveriges Nationalparker, n.d.)

The Koster Archipelago is a group of islands situated a few kilometers off the west coast of mainland Sweden. It is comprised of the two main islands North Koster and South Koster and surrounded by a large number of smaller islands and islets (Sveriges Nationalparker, n.d.)

Koster Islands

58°53'43.0"N 11°00'02.0"E

The Koster Islands have a year-round population of about 320 people, the majority of which live on South Koster. During summer, the population spikes as summer visitors come to enjoy the nature and go hiking, kayaking, snorkeling and diving.

South Koster, with an area of 8 square kilometers, is twice as large as North Koster. A large part of North Koster, as well as some parts of South Koster are a dedicated nature reserve (Kosteröarna, 2021). Even though the islands are small, the landscape is very varied. North Koster is relatively barren, consisting mostly of rocky soils and heather landscape, whereas South Koster has a lot of deciduous forests, meadows and cultivated land. The islands have plenty of beautiful white sandy beaches stretching into the ocean as well as some rocky beaches.

Before the 1920's, people had to get to the islands with their own boats. Nowadays there are 16 daily ferry rides going in between Strömstad to the Koster Islands which takes about 40 minutes. The two main ferry ports are Västra Bryggan on North Koster and Långegärde on South Koster. The ferry also departs from Vettnet, Ekenäs and Kilesand (Västtrafik, 2022). Once on the islands, the main way of transport is by foot or by bike. During the summer months, visitors can rent bikes and golf carts to get around faster. There is a cable ferry with place for 12 people connecting North Koster with South Koster.

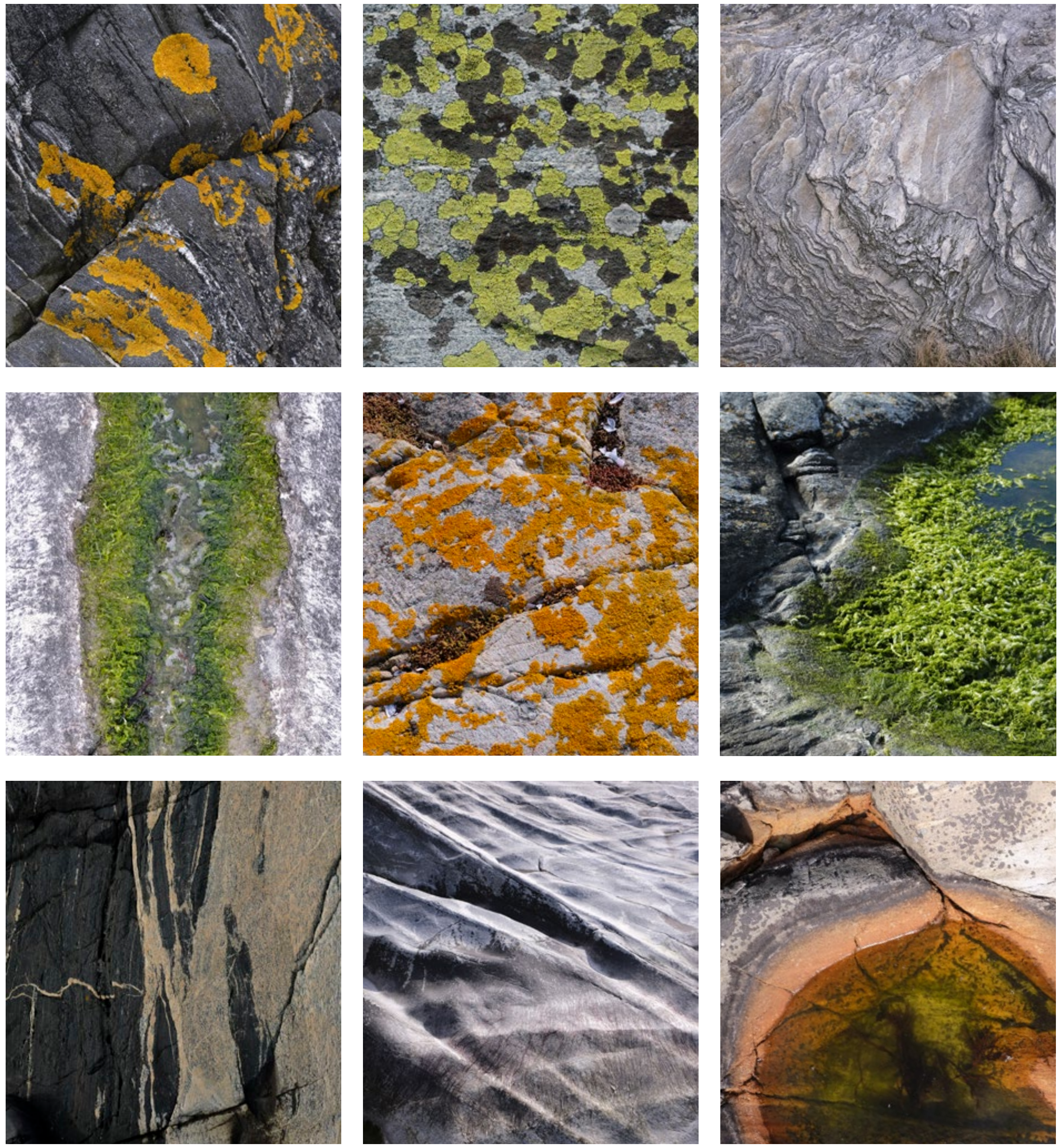
Views of Koster

View of the site of the exhibition hall

View of the bay

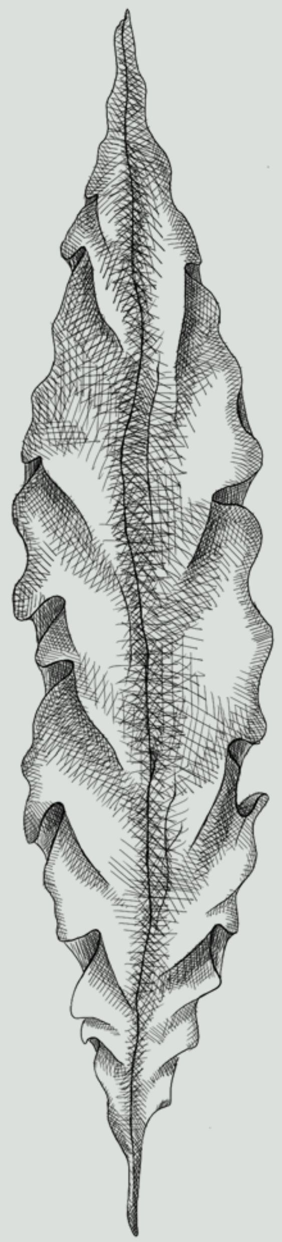
Bladderwrack growing on Koster

Colours of Koster



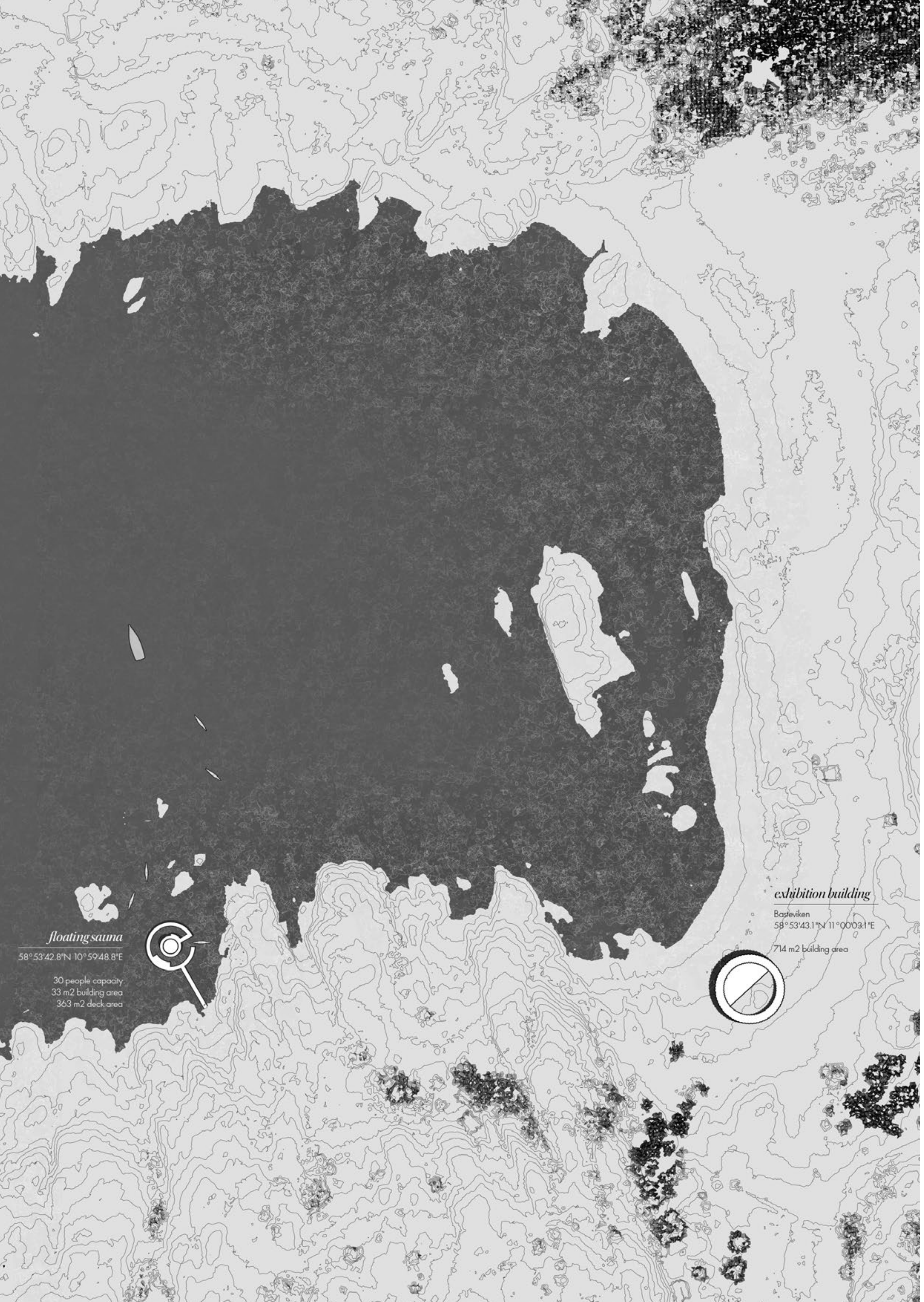
Photos from Basteviken, North Koster

Photos from Basteviken, North Koster



Saccharina latissima

DESIGN PROPOSAL



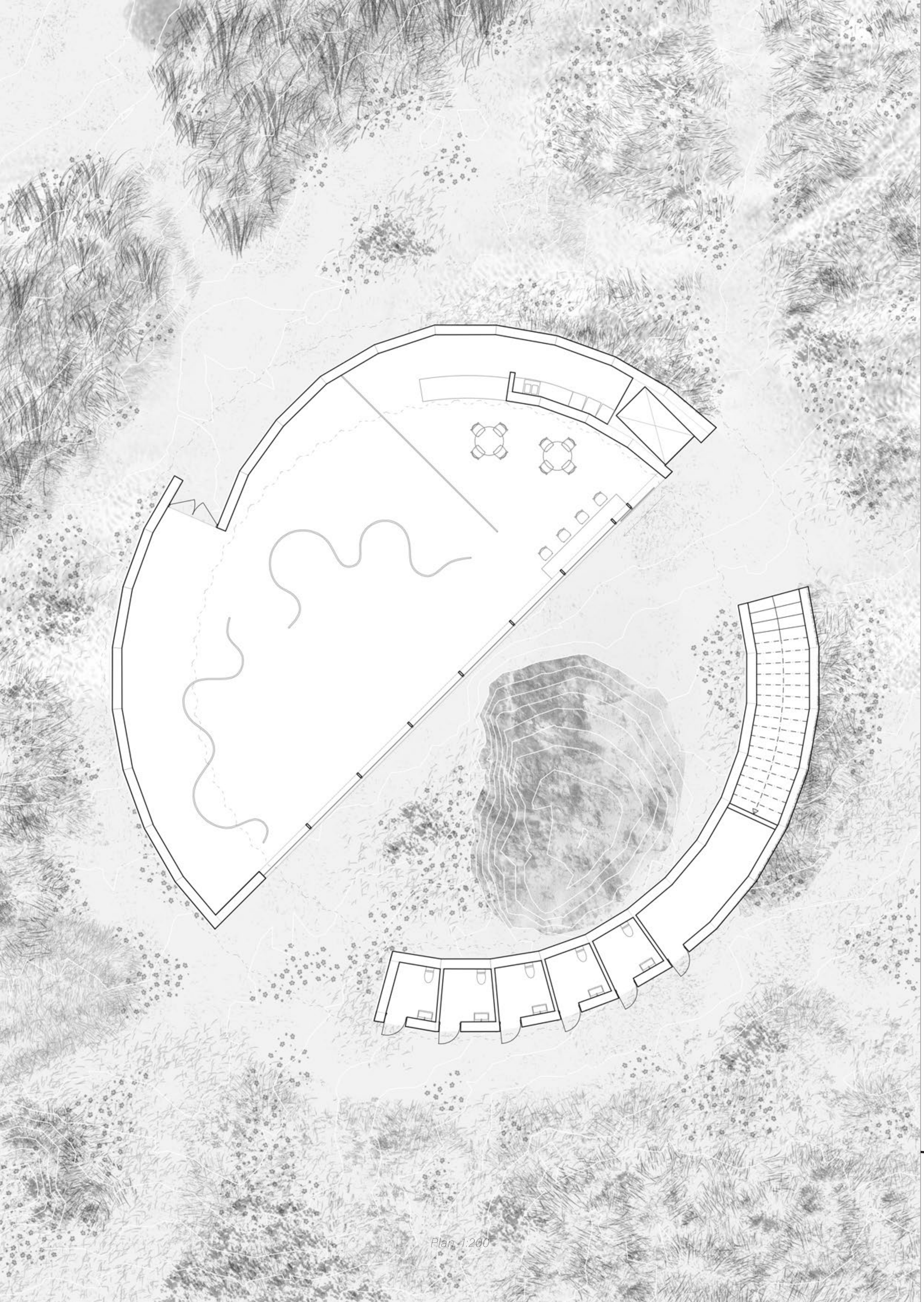
Two Structures

Summary and analysis of all the material experiments conducted, resulted in creating three different building materials: seacrete panels, bioplastic inflatable structures and kelp shingles which are implemented in a final design proposal of two structures. The design proposal was split into two separate buildings with the idea of showcasing the full potential of the created materials more clearly.

Based on a visit to the project site and analysis of the local conditions the design of the structures was made. Both of the buildings are formed on a round plan and designed in a way that ensures the center of the structure is wind protected. The buildings are mounted on the sites with a minimal impact to the existing terrain.

The first structure is located on the beach of the North Koster island. It is positioned on a side of the beach to allow keeping an undisturbed landscape. The buildings is centered around an existing rock and follows the hight curves of the terrain around it. It serves a function of an exhibition hall and a cafe.

The second buildings is hidden between the rocks located close to the site of the exhibition space. It is a floating structure accessible with a wooden pathway. The function of the building is a sauna open to the visitors at beach.



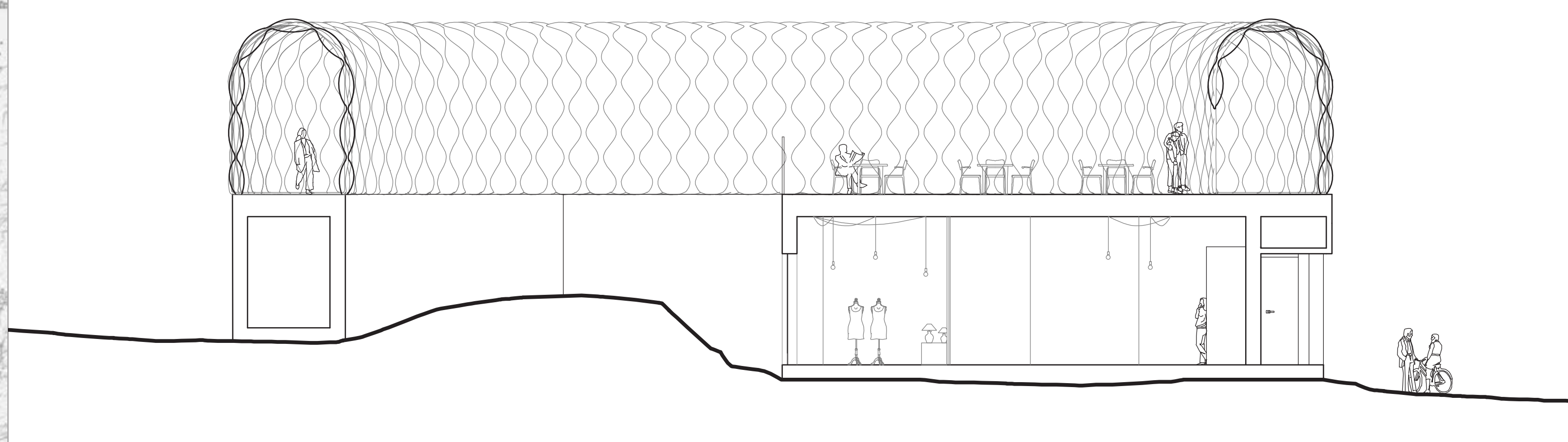
Plan 1:200

Exhibition Hall

It is a flexible, open space that provides area to exhibit different pieces of art related to seaweed and showcase information about algae. The exhibition area is meant to enhance the idea behind the building- to show the possibilities of seaweed and micro algae. The exhibition space is designed with the idea to showcase of different art, fashion and material pieces that are made out of seaweed and algae and that could inspire and teach the visitors.

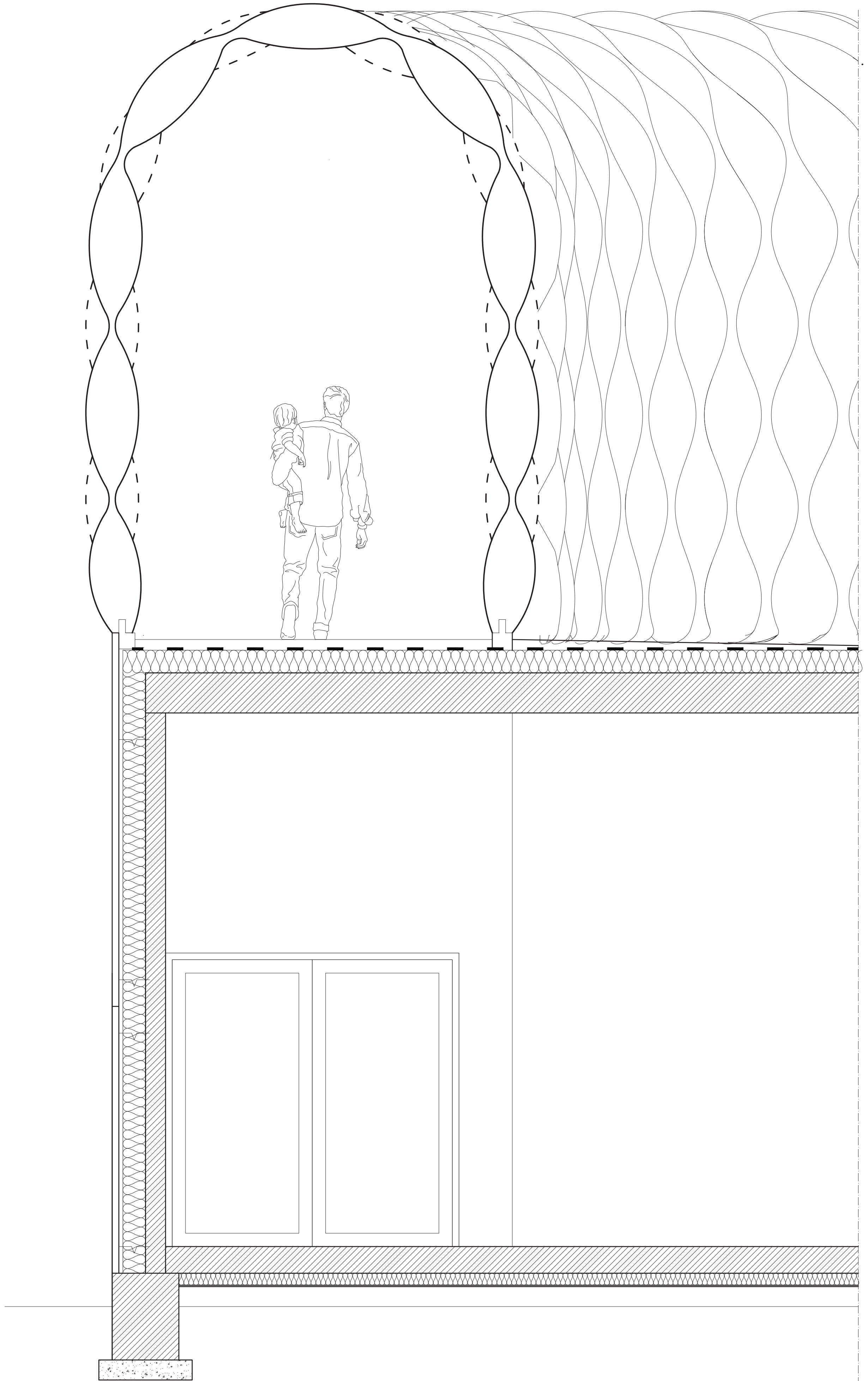
An additional function in the building is a cafe. The site is located near the beach and is visited by many tourist in the summer. A cafe is an attractive function for the visitors and a good addition to the exhibition space. Additionally seaweed is widely used in food industry. Another way of showing many possibilities of usage of algae could be to implement food made from it in the menu of the cafe.

The first type of material used in the proposal of this building is the bioplastic in a form of inflatable pieces on the upper floor of the exhibition space. The bioplastics form a corridor of colours that showcases the possibilities of this material and the variety of textures and hues it comes in.
The second type of material used in the project of the building is the seacrete. Seacrete is what the main structure of the building is made of. It is shaped into prefabricated blocks insulated with seagrass. On the outer side the blocks are covered with the seacrete panels that come in different colours and textures that are achieved by different ratios of additives.



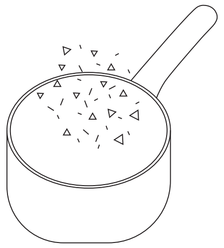
Section 1:200

Entrance view 1:40

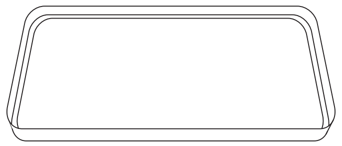


Detailed section 1:40

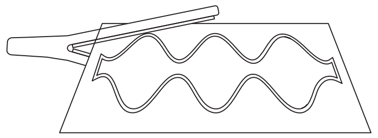
INFLATABLE BIOPLASTICS MAKING PROCESS



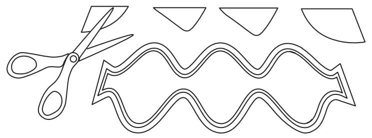
1. Mix the ingredients in the ratio of 2 agar : 2 glycerine : 75 water + additives and heat them up.



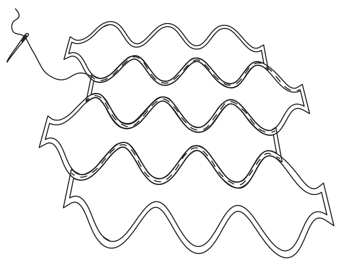
2. Pour the mixture into a flat non stick mould and leave to dry.



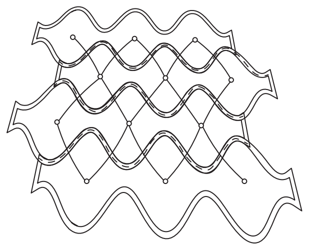
3. Take the bioplastic sheets out of the mould and weld them together in the right pattern using a welding machine.



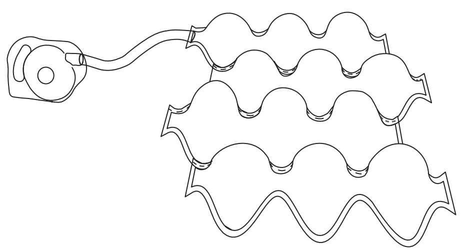
4. Cut off the residue bioplastic from the sheet (these can be reused).



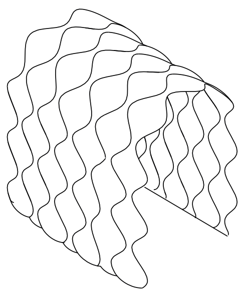
5. Weld the single pieces together and sew them to make sure they are securely attached.



6. Attach the tension rods to the inside of the bioplastic structure.



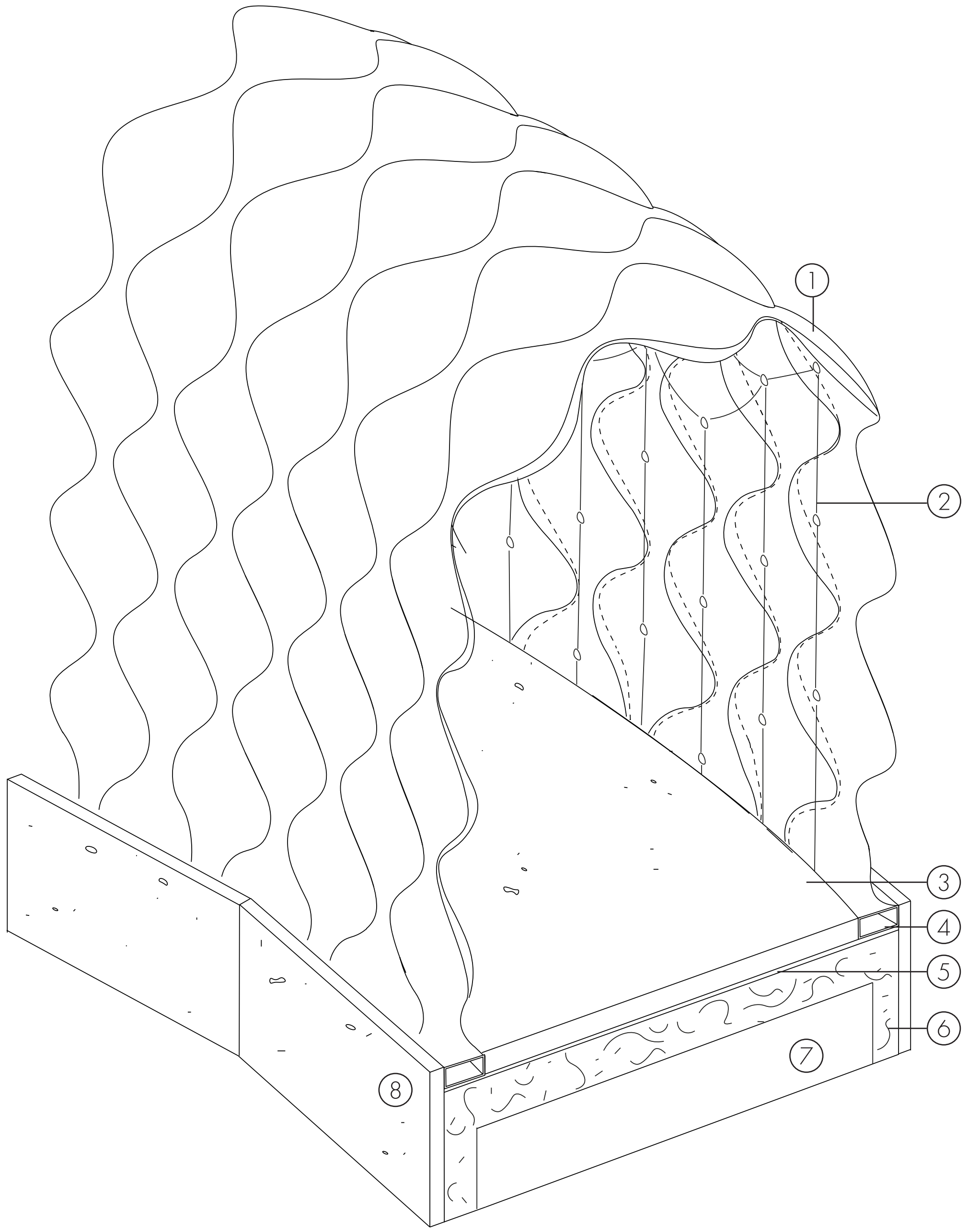
7. Inflate the structure (this will be done with a built-in airpump in the building).



8. Fully inflated structure forms the shape of the corridor.

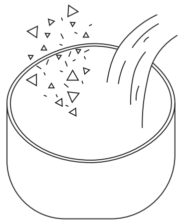
Mould used for bioplastic samples

Inflated bioplastic

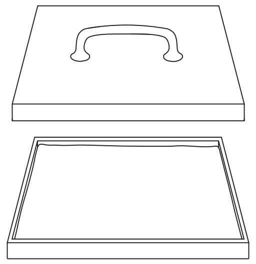


1. bioplastic material
2. tension rods substructure
3. 50 mm seacrete finishing layer
4. inflation system
5. water protection layer
6. 170 mm eelgrass insulation
7. 300 mm seacrete slab
8. seacrete facade panels

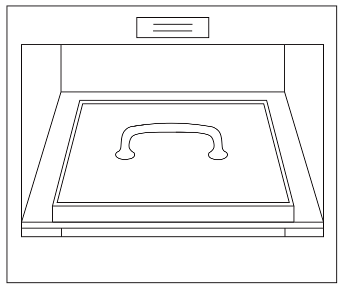
SEACRETE PANELS MAKING PROCESS



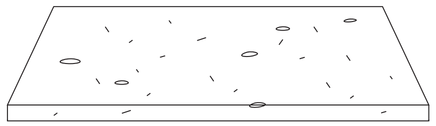
1. Mix alginate solution of 2,5 % with seashells and additives.



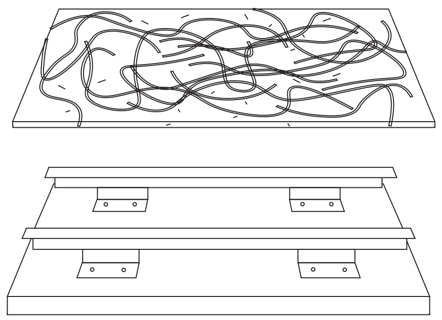
2. Pour the mixture into a mould and press it into a desired shape.



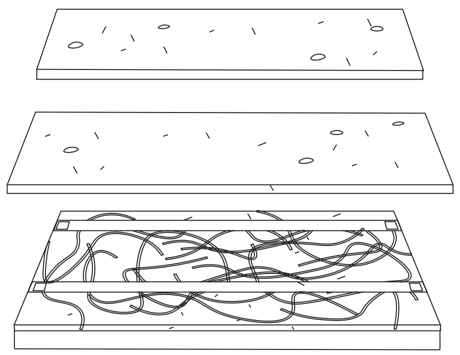
3. Put the mould into a dehydrator and dry in a temperature of 35 degrees.



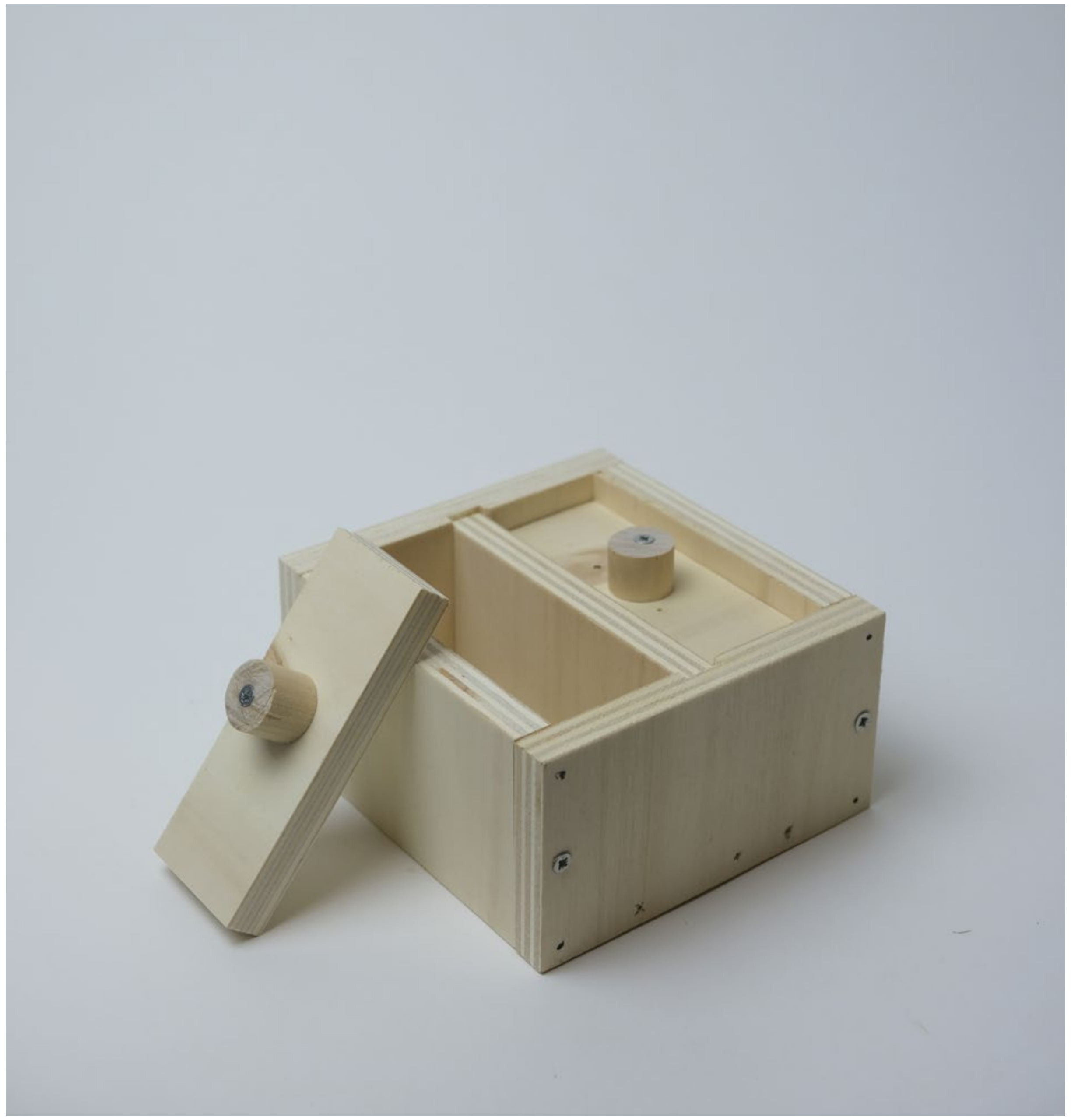
4. Take the mould out of the dehydrator after 12 hours and remove the panel from the mould.



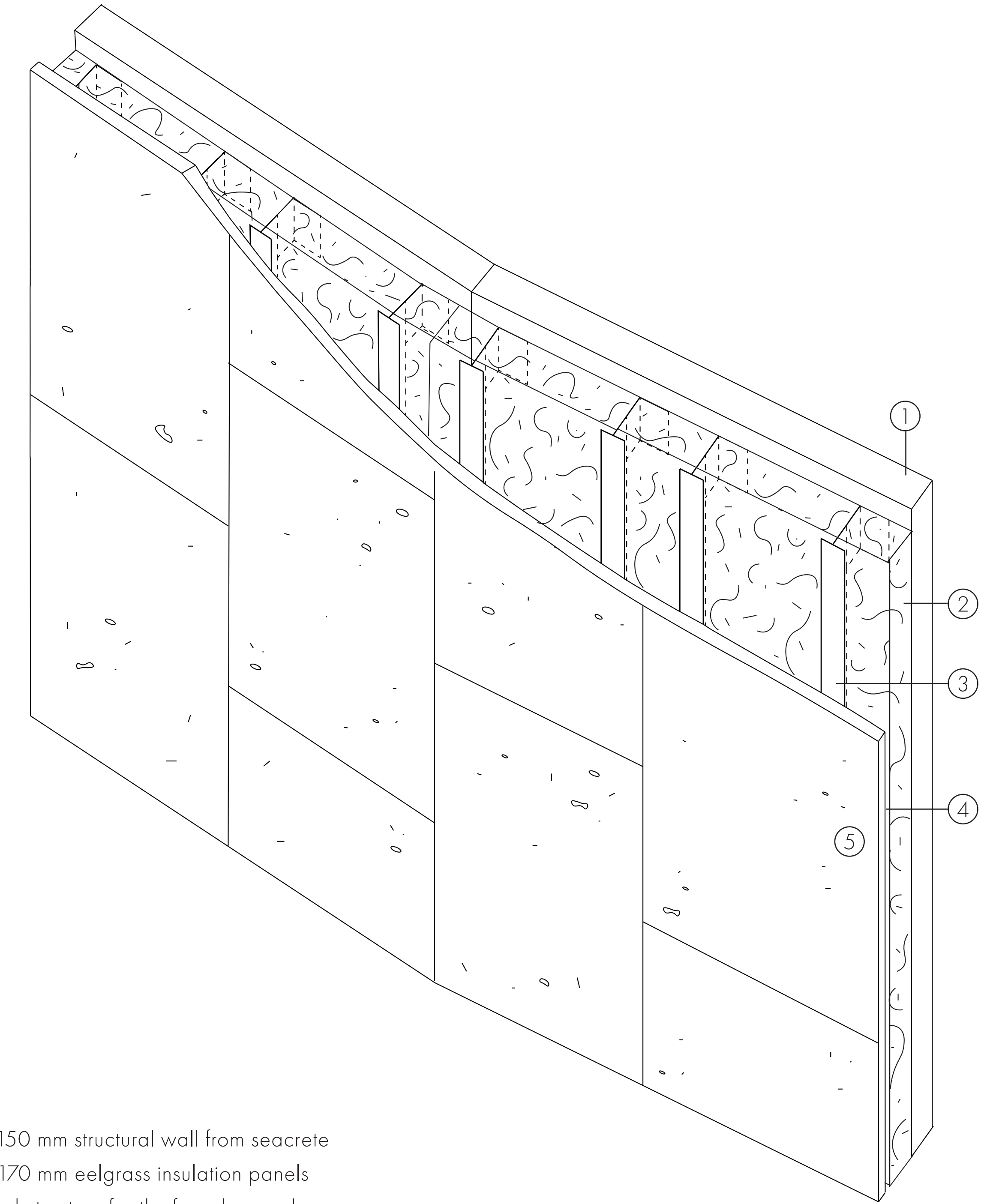
5. Attach the substructure for the panels on the loadbearing wall and insert seagrass insulation panels inbetween.



6. Attach the seacrete panels on top of the insulation.



Mould used for seacrete samples



1. 150 mm structural wall from seacrete
2. 170 mm eelgrass insulation panels
3. substructure for the facade panels
4. 30 mm air gap
5. 50 mm facade panels from seacrete

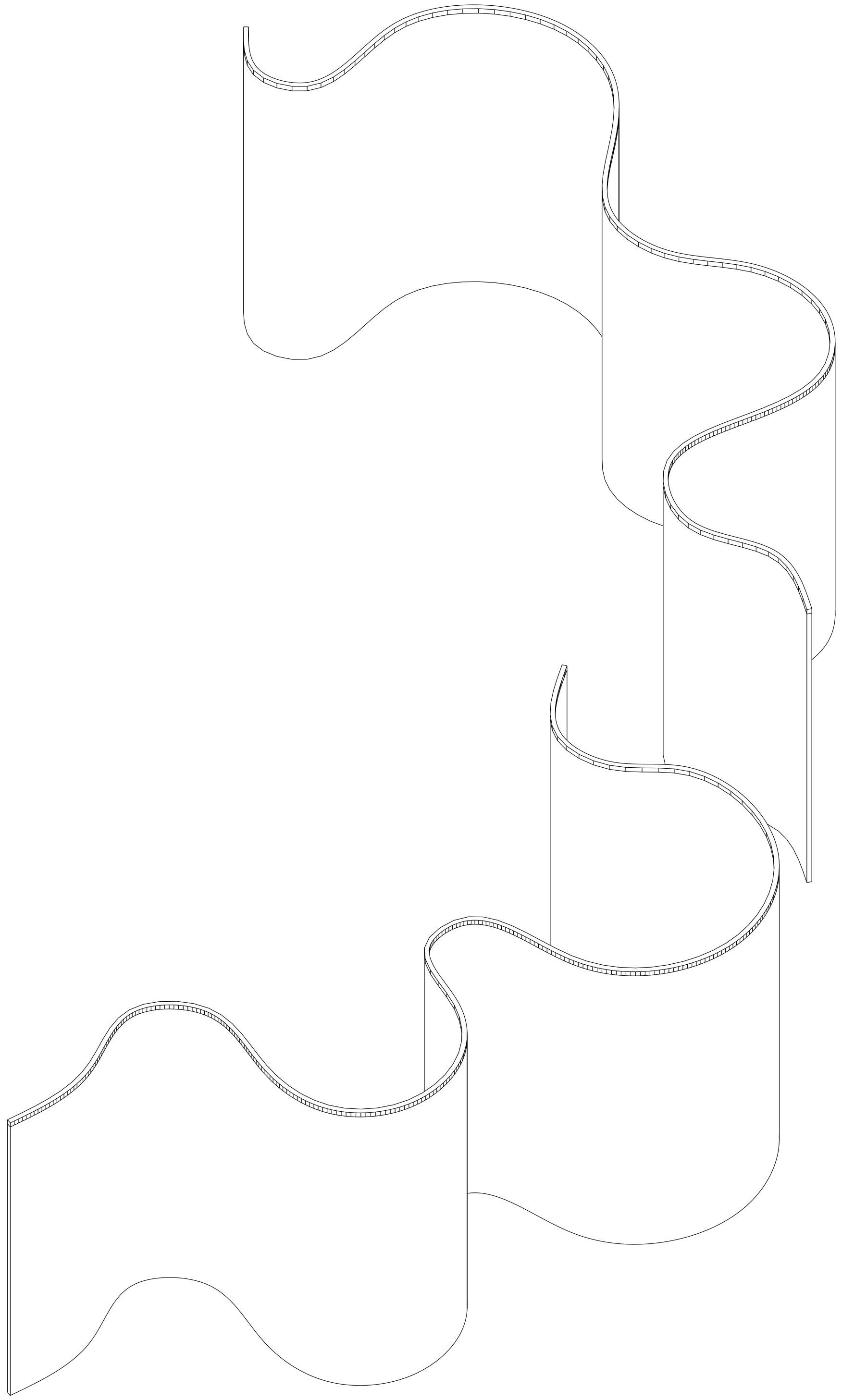
Seacrete samples

View inside the corridor

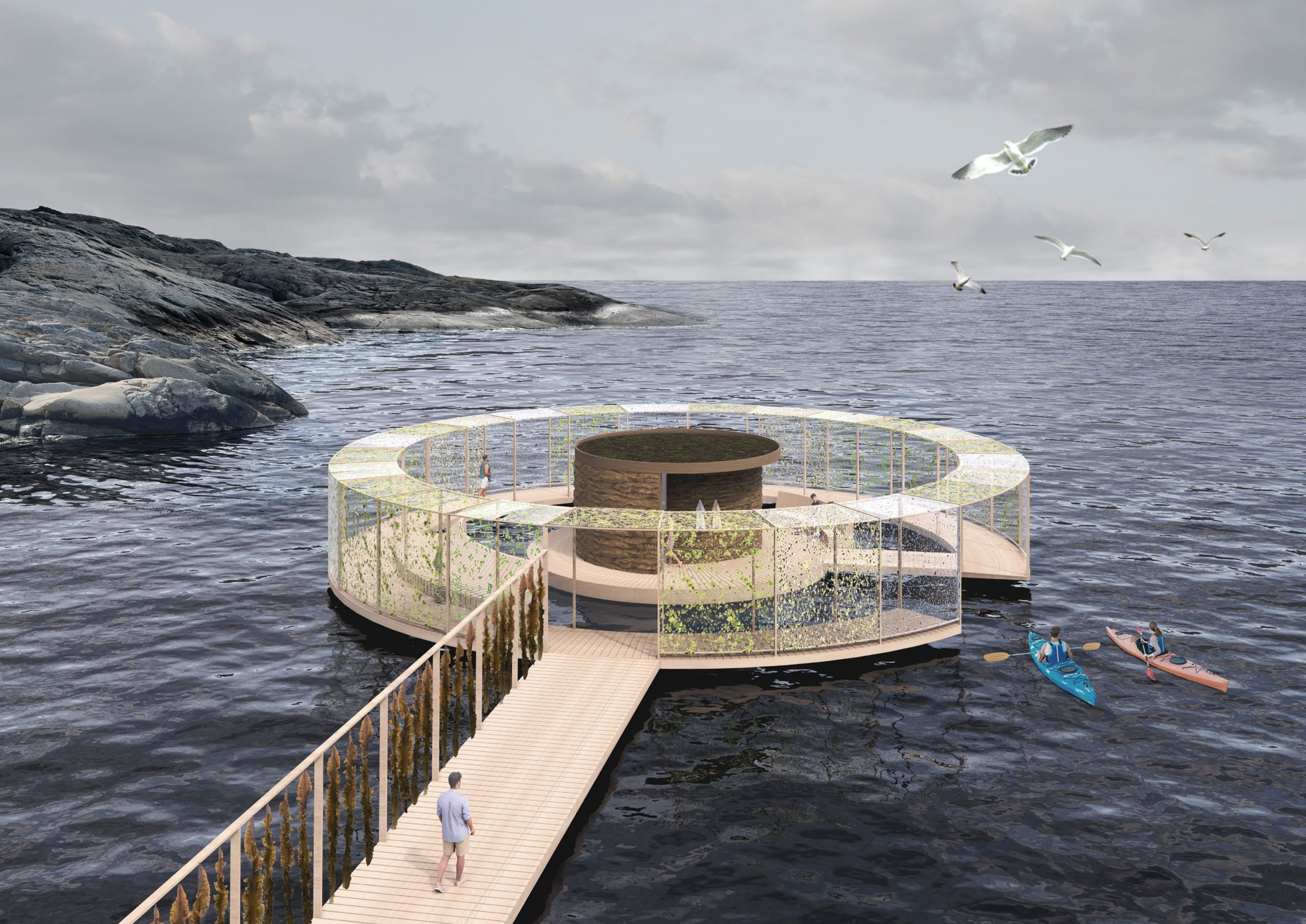
Facade and top view of the corridor

Exhibition view

SEAWEED EXHIBITION



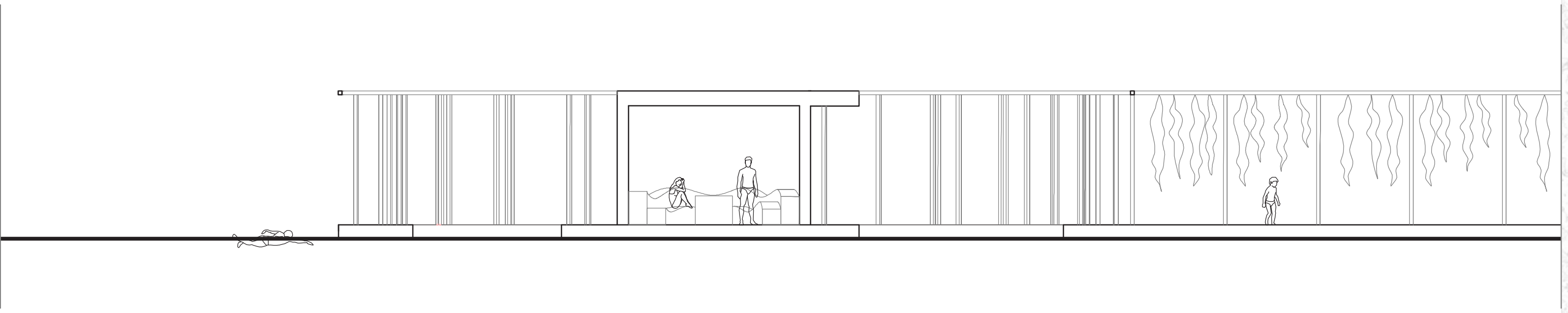
Bioplastic wall divider



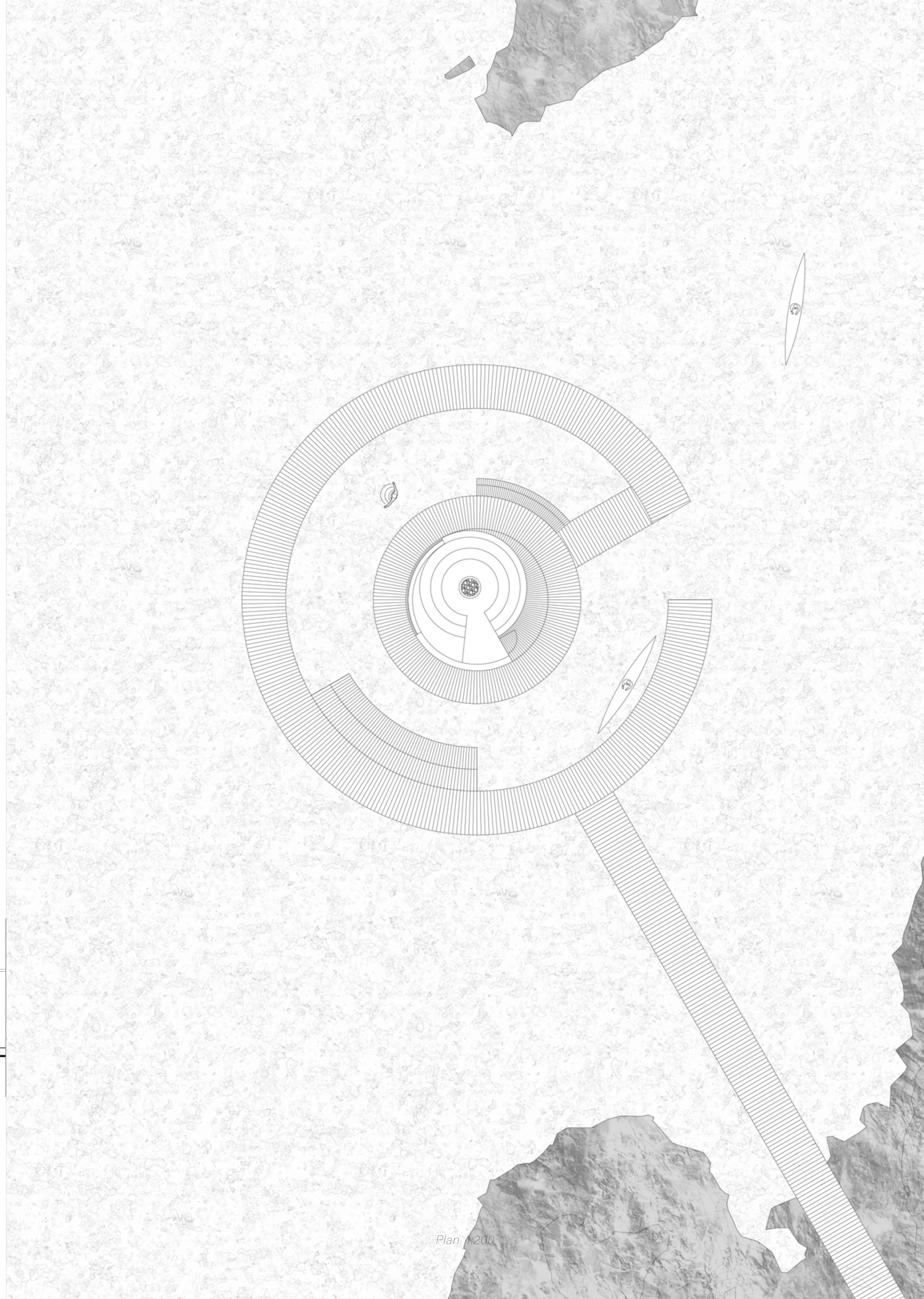
Sauna

This structure is located on water and consists of a sauna building, a wooden deck and a wooden pathway functioning as an access from the shore. The deck serves as a leisure area with two benches and parking spaces for kayaks. It is also covered from the wind by membranes streched around it.

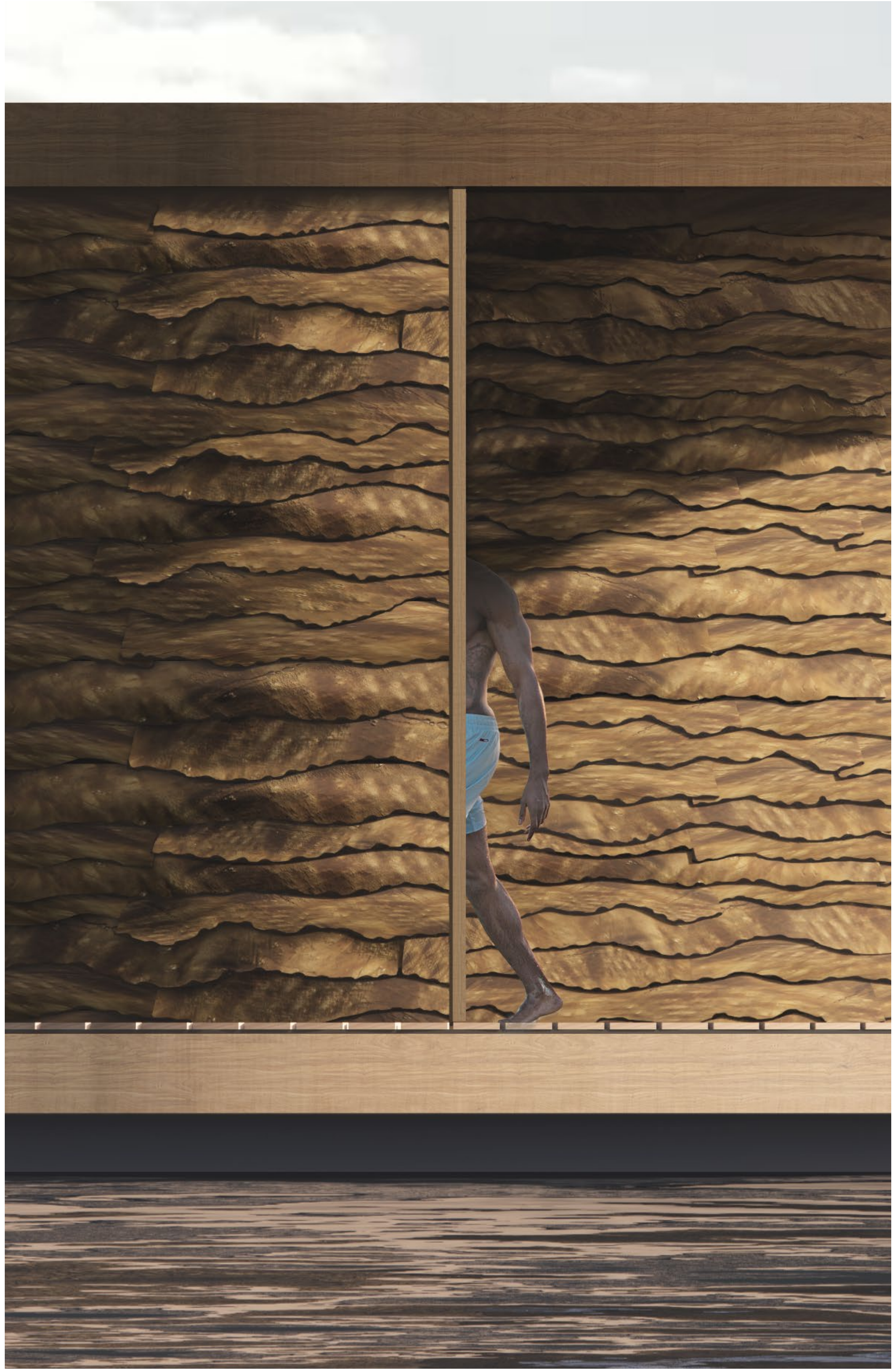
In this structure the seaweed shingles made from kelp leather are implemented as a cladding covering the whole sauna building. What is more the bioplastics serve as wind protective membranes streched on a wooden frame surrounding the deck. Finally the pieces of locally grown dried kelp are hanged on the pathway leading from the shore to the sauna building allowing the visitors to touch or pick them up.



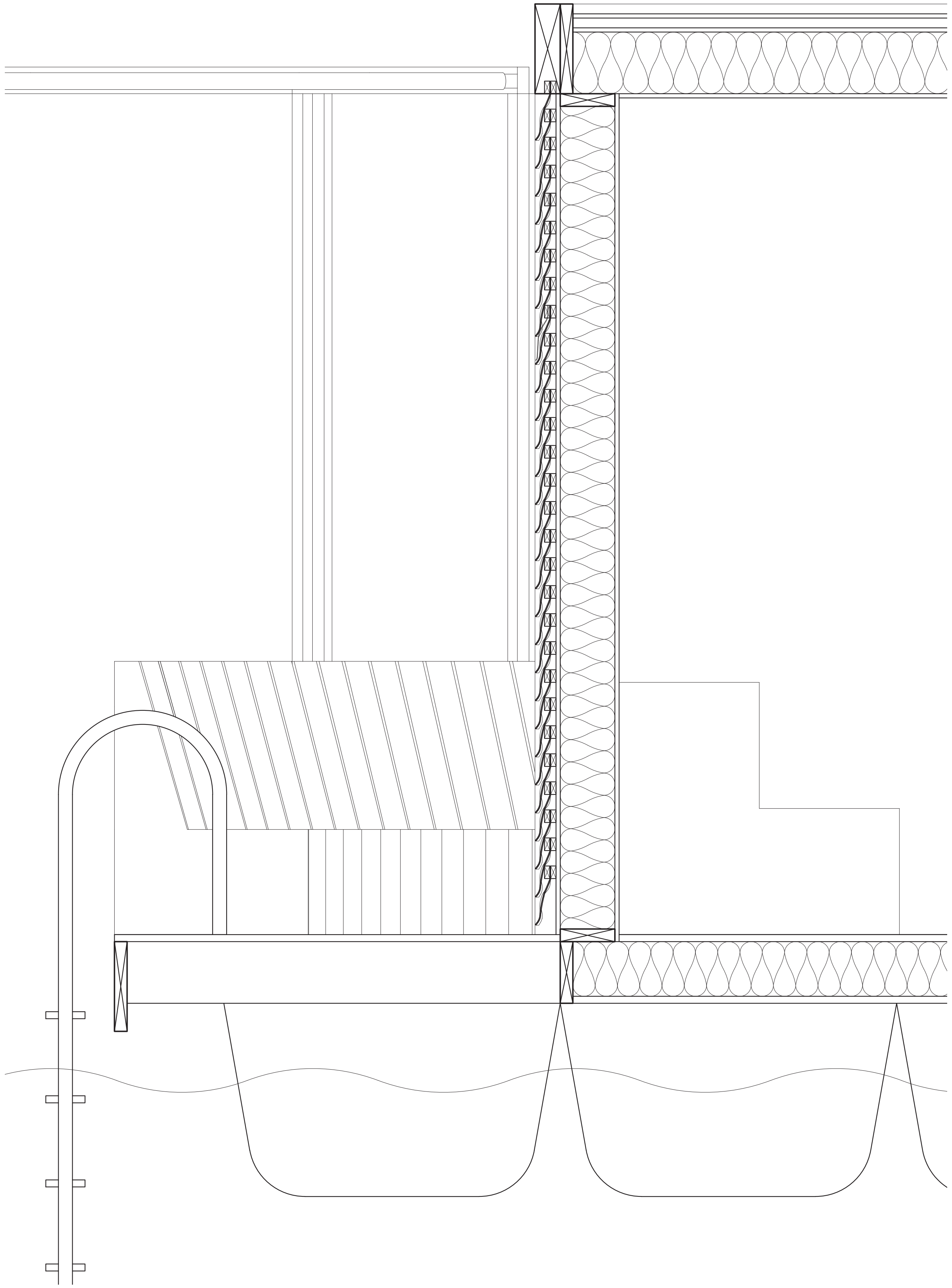
Section 1:200



Plan 1:200

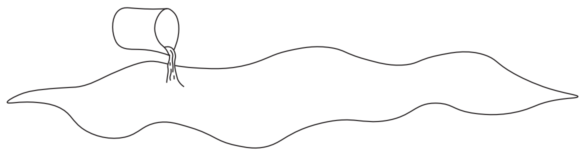


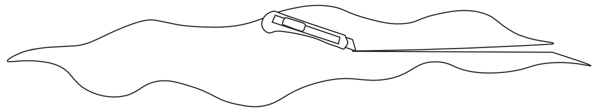
Entrance to the sauna



Section sauna

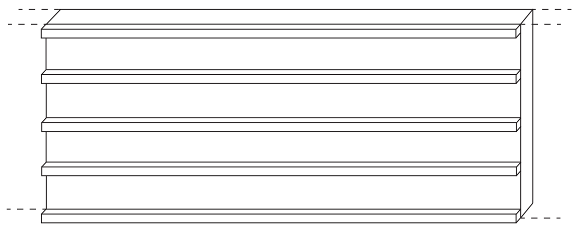
KELP SHINGLES MAKING PROCESS

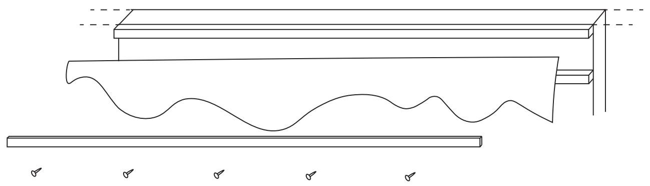




1. Spread glycerine over the kelp to make it flexible.

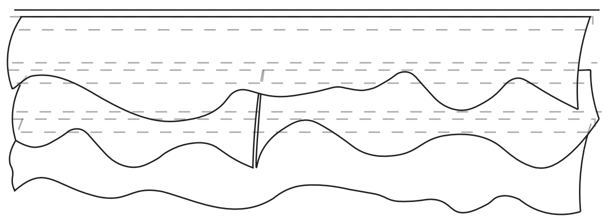
2. Cut each kelp piece in the middle where kelp is the thickest.





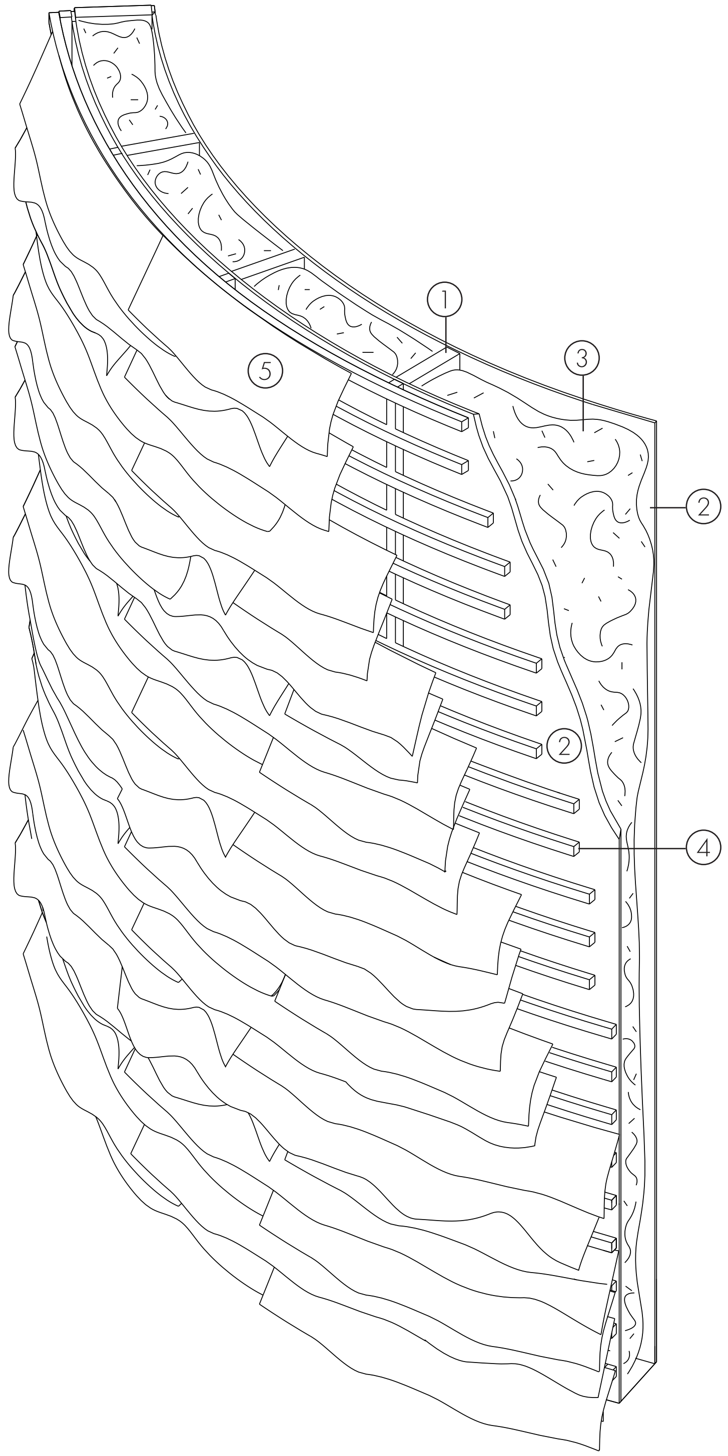
3. Attach substructure for the shingles on a load bearing wall. The distance between each of the wooden battens should be maximum 10 cm.

4. Attach the kelp shingles on the substructure using another batten to secure them.

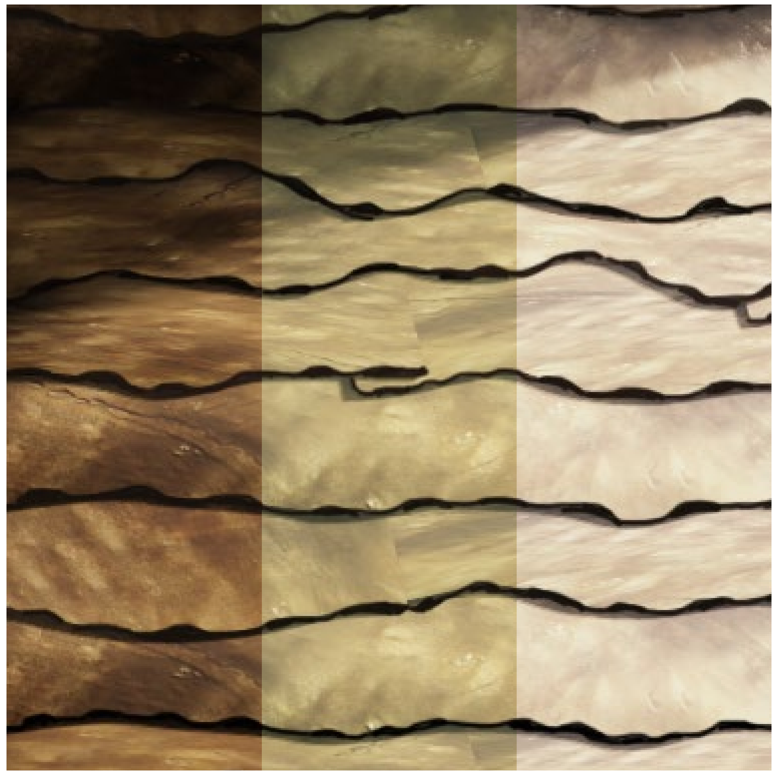


5. The shingles should overlap so the water doesn't get between them.

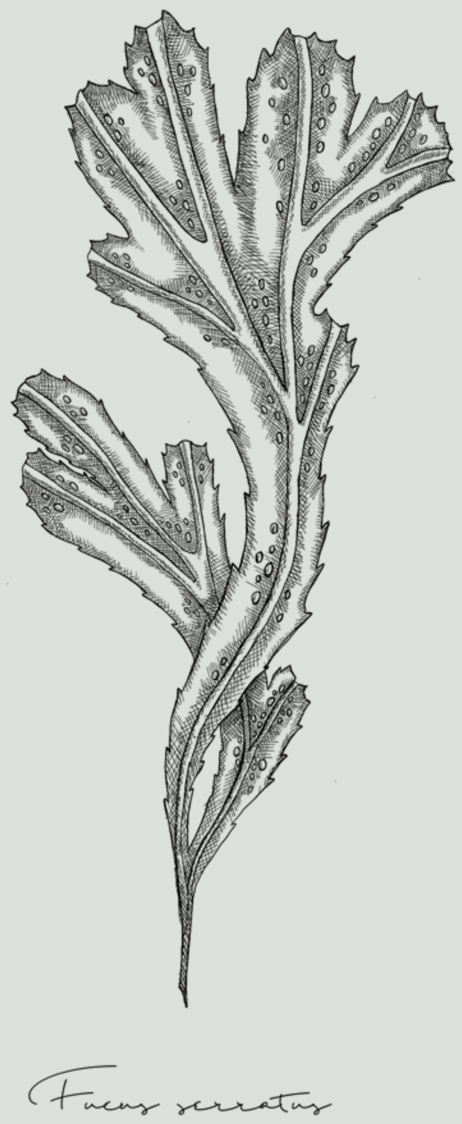
Model of shingles on the wall in scale 1:2



1. 45x195 mm load-bearing wooden pillars
2. 15 mm plywood panels
3. 195 mm eelgrass insulation
4. 28 mm shingles substructure
5. kelp shingles



Kelp colour change over time



CONCLUSION

Conclusion

This thesis aimed to explore and showcase the potential of seaweed in an architectural context. This has been achieved through studies of the material's historical use and its modern design implementations and through material experiments and resulted in the design of two buildings on North Koster, Sweden.

How can seaweed be introduced as an architectural element?

Throughout the material explorations, a variety of material properties and characteristics were found. The derivatives of seaweed like agar, carrageenan and alginate are great binders and can function as such in both bioplastics and seacrete panels. Kelp can be treated to remain flexible when dried and used as facade material. It is worth noting that the three main material categories included in this thesis (bioplastics, seacrete and kelp leather) are only some of the possible uses of seaweed within architecture.

What aesthetic and technical qualities of seaweed can be used as an input in an architectural design process?

Micro- and macroalgae can create a wide colour pallet. Seaweeds range from deep reds to browns and vivid greens and thereby add natural colours to the architectural design. In this thesis's case, the colourfull samples created during the material experiments, were the basis of the "corridor of colours" in the design proposal.

The different derivatives of seaweed also have different aesthetic and technical qualities, agar bioplastics being more transparent and easier to weld, whereas carrageenan bioplastics are rather translucent and more difficult to weld. This resulted in agar bioplastics being used in the inflatable structure. If translucency is preferred, carrageenan would be a good choice instead.

Kelp is extremely flexible when wet and hardens when dried. This material property and how it can relate to architecture could be explored more. Kelp also changes colour overtime with exposure to sunlight, from green/brown to white, which is an aspect taken into consideration with the design of the sauna.

What is the potential of seaweed in the future of architecture and building construction?

Seaweed is a sustainable material with many uses. The spike in popularity in researching the potential of seaweeds has increased significantly over the past decade, and assume-ably will continue doing just so in the future. However, for the material to be sustainable, it has to be harvested in a sustainable way. Wild seaweed should not be harvested in bulk, but instead grown in large seaweed farms where they improve ocean waters while growing.

Reflection

The aim of this thesis was to find alternatives to popular building materials with usage of algae and seagrass and implement them in a building proposal. Pretty soon in the process it was discovered that it is not possible to work through and investigate every aspect and quality of the material that makes it a suitable building element in the amount of time given. That lead to narrowing down the aspects of seaweed materials that were investigated. The main focus of this research ended up to be an exploration of aestethical qualities of the samples as well as the abilities of certain materials to perform as interesting architectural elements for example inflatable structures. Some of the technical qualities like water resistance and strength were tested to a limited extend or researched through literature studies. They were only investigated to a degree that allowed to believe they could perform in a real life setting if the explored techniques were applied. If the researched presented in this thesis was ever continued the next step of the investigation would be to test these qualities and adjust the possibilities of the design implementation accordingly to the results.

During the investigation it was also discovered that seaweed has some delimitations when it comes to perfoming as a building material. There were some experiments made with an idea to achieve a pressed brick from seaweed, but because of algae characteristics it would not bind and it could not perform as a load bearing material. Because of this discovery some non-algae additives were needed to get the desired results which was not the original plan of this thesis.

When it comes to types and spieces of marine plants it is important to mention that the ones used in this investigations were only these that could be locally accessed or bought. There is a possibility that there are some spieces of seaweed, seagrass and microalgae that could perform better in the experiments made or could give different results. If these explorations were continued an important study could be to test a bigger range of spiecies than presented in this thesis.

A crucial aspect to reflect upon when it comes to this thesis is the fact that the material research and experiments were started prior to the design proposal. As a result the building proposal was based on and adjusted to the material findings. Even though this was done deliberately in this project it is important to realise that it is not a usual situation that would occur in an architectural practice. It is more common that the materials are selected basing on a certain building design not the other way around.

This way of working also resulted in some issues during the design process that would probably not occur in a usual architectural investigation. What that means is that for example the form of certain architectural elements had to be redrawn and adjusted multiple times so that the material could be implemented and showcased in a good way.

Finally it needs to be mentioned that this thesis is not an overview of all the possible implementations of seaweed and algae as a building material. The material investigations made in the course of this explorations were only meant to show an idea of what can be achieved with usage of seaweed and inspire future studies on this matter.

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Joline Schikan & Barbara Gwóźdź

Master Thesis Spring 2022 | Chalmers School of Architecture | Department of Architecture and Civil Engineering

APPENDIX

Material Experiments

The Seaweed Archives

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Master Thesis Spring 2022 | Chalmers School of Architecture | Department of Architecture and Civil Engineering

Appendix: Material Experiments

This document in an appendix for "The Seaweed Archives" Master Thesis. On the following pages experiments that were a part of this thesis are documented, described and evaluated. This appendix consists of three main sections: Bioplastics, Seacrete and Kelp Leather. The experiments presented in this document are described using three digit numbers. The meaning of the number system should be understood as follows:

1 2 3

section of the experiment

number of the experiment according to time order

Experiment section numbers:

0 - Bioplastic experiments
1 - Seacrete experiments
2 - Kelp experiments

A selection of the bioplastic material experiments

A selection of the seacrete and kelp leather material experiments

Ingredients

Agar	a hydrocolloid substance extracted from some species of the red algae.
Alginate	a hydrocolloid that can be extracted from cell walls of brown algae.
Astaxanthin	caretonoid extracted from microalgae used commonly as food colouring.
Spirulina	cyanobacterium (microalgae) with a characteristic strong green colour.
Blue Spirulina	cyanobacterium (microalgae) with a characteristic strong blue colour.
Calcium Chloride	chloride salt of calcium commonly used as food preservative.
Carrageenan Kappa	hydrocolloid derived from spieces of red algae.
Glycerine	sugar alcohol often used as base of chemical mixtures.
Oyster shell powder	powder made during the process of this thesis from crushed oyster shells.
Seaweed Dye	dye made during the process of this thesis by cooking brown algae.

BIOPLASTICS

The Setup

GRADUATED CYLINDER
SAUCEPAN
YARN
HOTPLATE
ERLENMEYER FLASK
SCALE
CLOTHES PEG
WOODEN FRAME PIECES
WHISK
SIEVE
SPOON
KNIFE
SCISSORS
MOULD
MOULD
MOULD

Evaluation of the experiments

The batch of bioplastic samples was made to investigate possibilities of using them as a functional material with good aesthetic values. To help evaluate the samples, they were assessed using eight different criteria. These criteria were based both on the looks of the material and the technical attributes. First five criteria address the aesthetic values of the samples and the remaining three focus on the technical possibilities of the material. All of the samples were evaluated between one to four weeks after the making to ensure that they were completely dry and the color durability of the samples could be evaluated properly. However, the time of the photographic documentation of the samples may vary.

Visual Experience

This criteria evaluates how the material looks. The scale ranges from "bad" to "good" but in fact what is evaluated here is how well the material would look if applied in the building project. When judging "bad" or "good" what is taken into consideration is the shape of the sample, the color and the homogeneity of the material.

Texture

Texture refers both to visual and tactile experience of the sample. This criteria evaluates if the sample is "rough" or "smooth" when looked at and touched. What can influence the roughness of the sample are the ingredients used (e.g. when spirulina is only partially blended in the material it creates a rough texture on the surface) or the additives like kelp or dulse flakes.

Glossiness

This criteria refers to the reflective abilities of the material. The scale ranges between "glossy" and "matte". The experiments vary when it comes to reflectiveness but the main difference is noticeable between material samples made from agar and carrageenan. The carrageenan samples are matte and paper-like while the agar samples are more glossy.

Colour Durability

The evaluation for this particular criteria is made over time. The most visible changes can be seen after four weeks from the sample making. It can also be noticed that the color durability issue appears mostly in experiments with astaxanthin.

Transparency

Transparency refers to how see-through the samples are. This may also vary depending on many aspects. Some of the materials turned out translucent, some almost completely transparent and some opaque.

Flexibility

This criteria was created to evaluate technical possibilities of particular samples. Some of them turned out very brittle and hard and some more flexible. The ability of the material to be flexible depends mostly on the amount of glycerine added to the mixture. It can also vary depending on the thickness of the particular sample. Thinner samples tend to be more bendable.

Thickness

Bioplastics made from seaweed derivatives have limited abilities when it comes to thickness. The samples can usually become only couple of millimeters thick. This is because during drying process the material shrinks around 50% in thickness. Moreover, when poured too thick, the sample will mould. However the experiments that were made still vary in this particular criteria and that is why we evaluate the samples in this category as well.

Deformation

While drying, algae bioplastic tends to wrinkle. The reason for that is that the water evaporates and causes the material to shrink. This can be controlled to some extend depending on the drying process. Some of the samples were dried by hanging them up and some by leaving them on a flat surface. Some were also put in a dehydrator. All of these aspects influenced the final deformation of the material.

No. 001

250ml water / 12g agar / 9ml glycerine / 6g spirulina

Visual experience
Bad — Good

Texture
Rough — Smooth

Glossiness
Matte — Glossy

Colour Durability
Not durable — Durable

Transparency
Opaque — Transparent

Flexibility
Brittle — Flexible

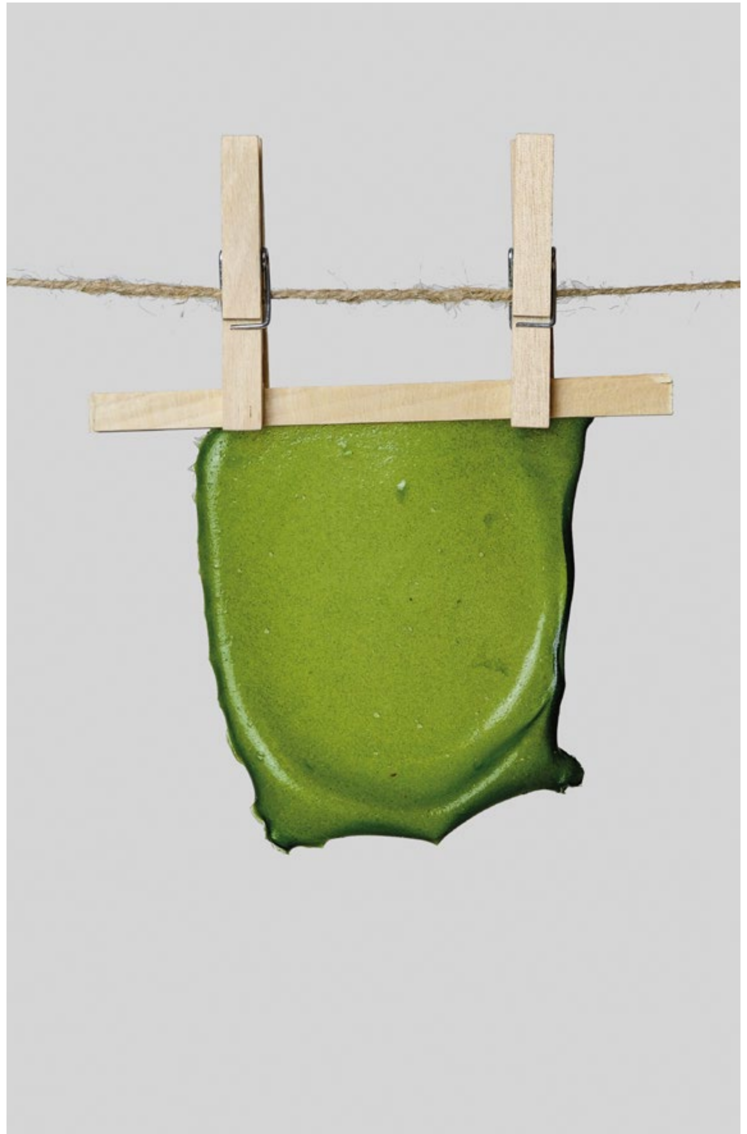
Thickness
Thin — Thick

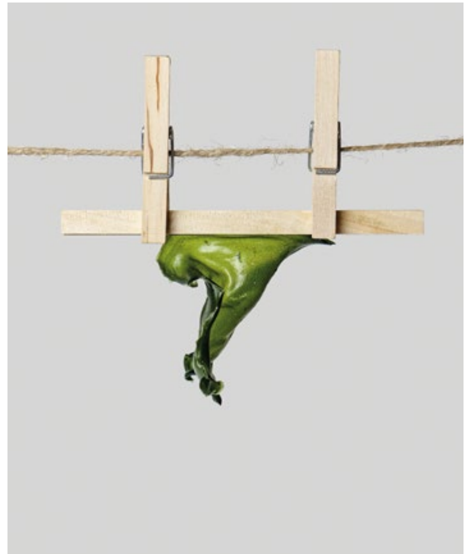
Deformation
Flat — Wrinkled

Observations: very dark colour, thick, wrinkles when drying

No. 002

250ml water / 10g agar / 3g spirulina





Visual experience
Bad — Good

Texture
Rough — Smooth

Glossiness
Matte — Glossy

Colour Durability
Not durable — Durable

Transparency
Opaque — Transparent

Flexibility
Brittle — Flexible

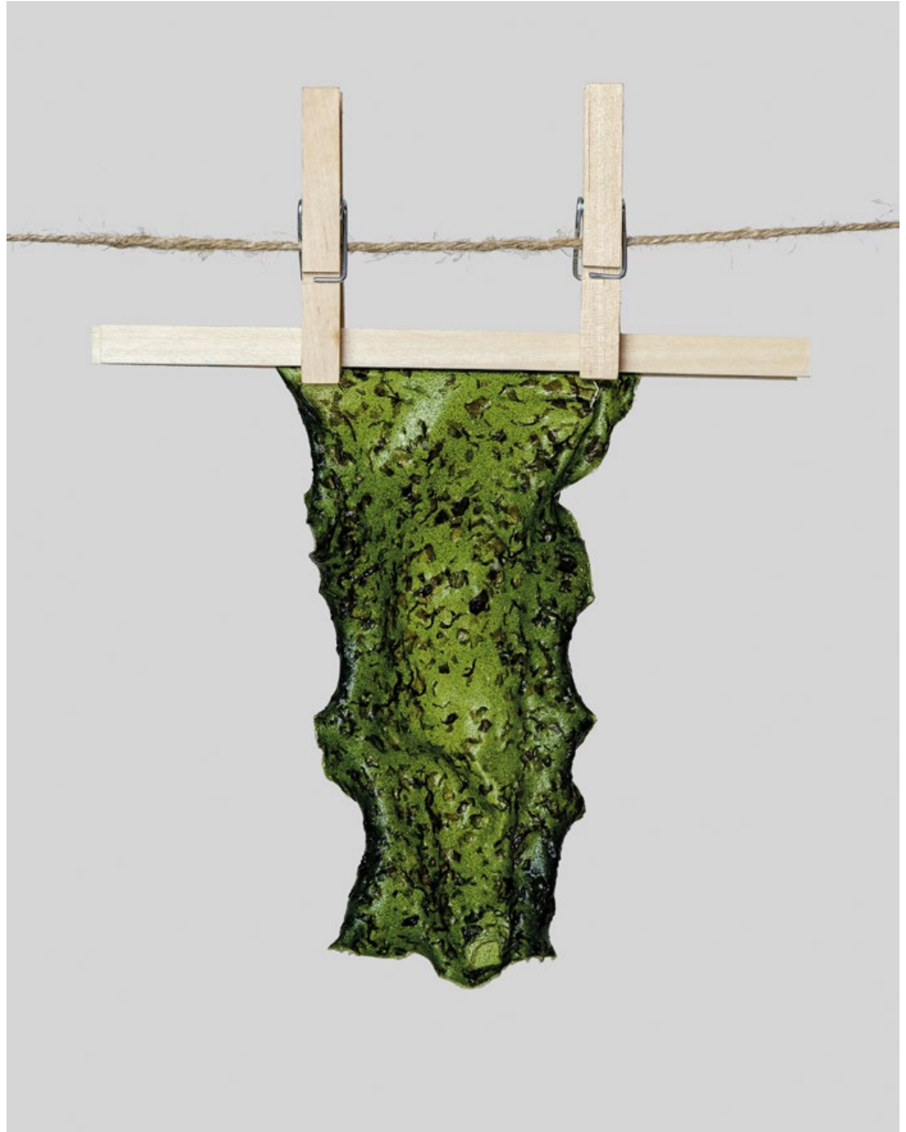
Thickness
Thin — Thick

Deformation
Flat — Wrinkled

Observations: light green colour, better consistency when pouring, lack of glycerine makes sample completely harden when dried

No. 003

250ml water / 10g agar / 9ml glycerine / 1g spirulina / 1g dulse flakes



Visual experience — *Bad* / *Good*

Texture — *Rough* / *Smooth*

Glossiness — *Matte* / *Glossy*

Colour Durability — *Not durable* / *Durable*

Transparency — *Opaque* / *Transparent*

Flexibility — *Brittle* / *Flexible*

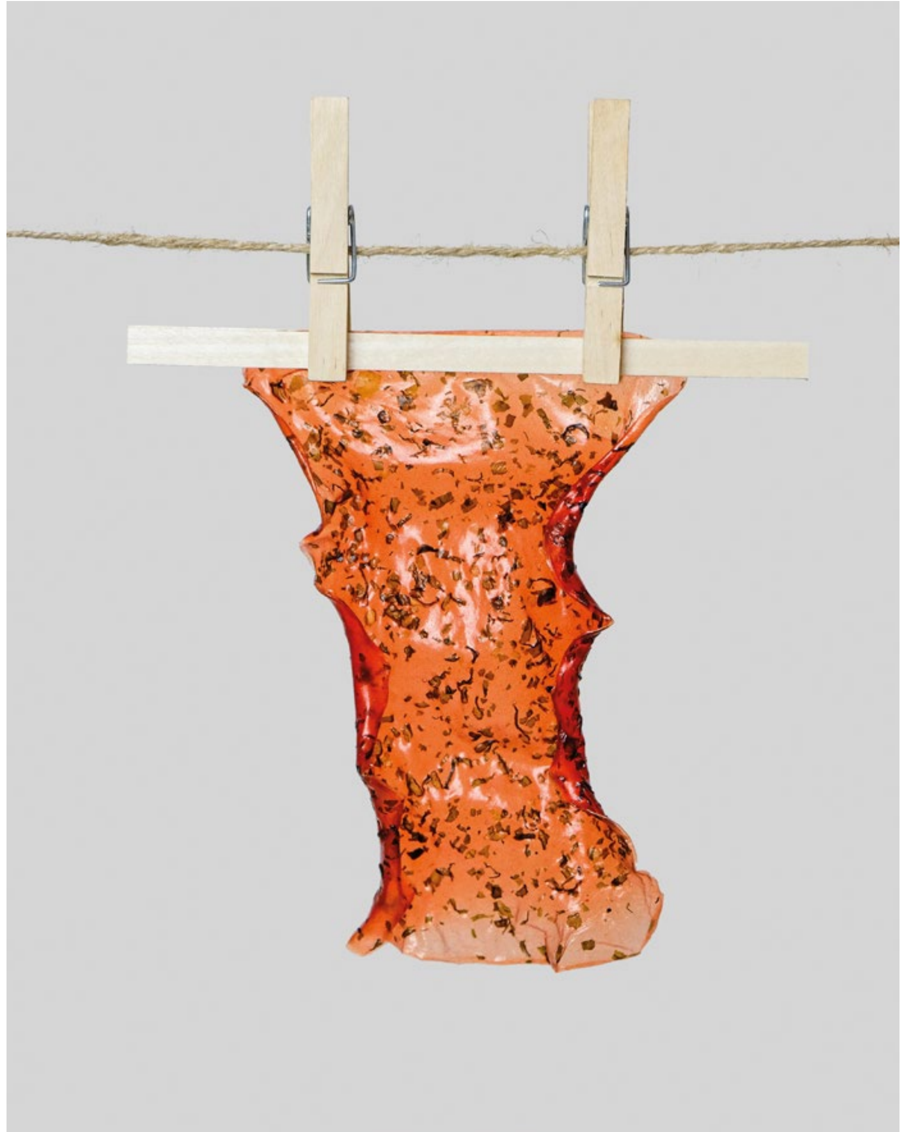
Thickness — *Thin* / *Thick*

Deformation — *Flat* / *Wrinkled*

Observations: light green colour, wrinkled a lot when drying, interesting texture

No. 004

250ml water / 10g agar / 9ml glycerine / 1g astaxanthin / 1g dulse flakes



Visual experience — *Bad* / *Good*

Texture — *Rough* / *Smooth*

Glossiness — *Matte* / *Glossy*

Colour Durability — *Not durable* / *Durable*

Transparency — *Opaque* / *Transparent*

Flexibility — *Brittle* / *Flexible*

Thickness — *Thin* / *Thick*

Deformation — *Flat* / *Wrinkled*

Observations: Deep red colour but the red faded overtime, wrinkled a lot when drying

No. 005

150ml water / 3g agar / 3ml glycerine / 0.5g spirulina

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Glossiness
Matte — *Glossy*

Colour Durability
Not durable — *Durable*

Transparency
Opaque — *Transparent*

Flexibility
Brittle — *Flexible*

Thickness
Thin — *Thick*

Deformation
Flat — *Wrinkled*

Observations: interesting speckles effect when spirulina is added in the end without fully blending it, shrinks less then samples before

No. 006

150ml water / 3g agar / 3ml glycerine / 0.5g astaxanthin / 2 pieces of seaweed

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Glossiness
Matte — *Glossy*

Colour Durability
Not durable — *Durable*

Transparency
Opaque — *Transparent*

Flexibility
Brittle — *Flexible*

Thickness
Thin — *Thick*

Deformation
Flat — *Wrinkled*

Observations: this sample lost its colour over time, wrinkled a lot.

No. 007

150ml water / 3g agar / 1ml glycerine / 0.5g blue spirulina

Visual experience — *Bad* / *Good*

Texture — *Rough* / *Smooth*

Glossiness — *Matte* / *Glossy*

Colour Durability — *Not durable* / *Durable*

Transparency — *Opaque* / *Transparent*

Flexibility — *Brittle* / *Flexible*

Thickness — *Thin* / *Thick*

Deformation — *Flat* / *Wrinkled*

Observations: blue spirulina doesn't want to dissolve fully into the mixture, instead it bleeds into bioplastic overtime during drying, wrinkles and shrinks a lot

No. 008

150ml water / 3g agar / 6ml glycerine / 0.5g blue spirulina

Visual experience — *Bad* / *Good*

Texture — *Rough* / *Smooth*

Glossiness — *Matte* / *Glossy*

Colour Durability — *Not durable* / *Durable*

Transparency — *Opaque* / *Transparent*

Flexibility — *Brittle* / *Flexible*

Thickness — *Thin* / *Thick*

Deformation — *Flat* / *Wrinkled*

Observations: Thinner layer was poured which made the bioplastic more fragile, more shiny and see-through, the additional glycerine made the sample more sticky, wrinkled less than the other samples

No. 009

150 ml water / 4 g agar / 7 ml glycerine / ~1 g green spirulina

Visual experience

Bad — Good

Texture

Rough — Smooth

Glossiness

Matte — Glossy

Colour Durability

Not durable — Durable

Transparency

Opaque — Transparent

Flexibility

Brittle — Flexible

Thickness

Thin — Thick

Deformation

Flat — Wrinkled

Observations: Spirulina was blended from the start which resulted in light green colour of the sample, shrinked more than 50% of the original size

No. 010

150 ml water / 4 g agar / 7 ml glycerine / ~1 g green spirulina / ~1 g blue spirulina

Visual experience

Bad — Good

Texture

Rough — Smooth

Glossiness

Matte — Glossy

Colour Durability

Not durable — Durable

Transparency

Opaque — Transparent

Flexibility

Brittle — Flexible

Thickness

Thin — Thick

Deformation

Flat — Wrinkled

Observations: The sample became more shiny and see-through, was left to dry flat and did not wrinkle.

No. 011

150ml water / 3g agar / 3ml glycerine / 1g kelp powder

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Glossiness
Matte — *Glossy*

Colour Durability
Not durable — *Durable*

Transparency
Opaque — *Transparent*

Flexibility
Brittle — *Flexible*

Thickness
Thin — *Thick*

Deformation
Flat — *Wrinkled*

Observations: interesting terrazzo effect, almost no wrinkles

No. 012

150ml water / 3g agar / 1g glycerine / 1g red seaweed powder

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Glossiness
Matte — *Glossy*

Colour Durability
Not durable — *Durable*

Transparency
Opaque — *Transparent*

Flexibility
Brittle — *Flexible*

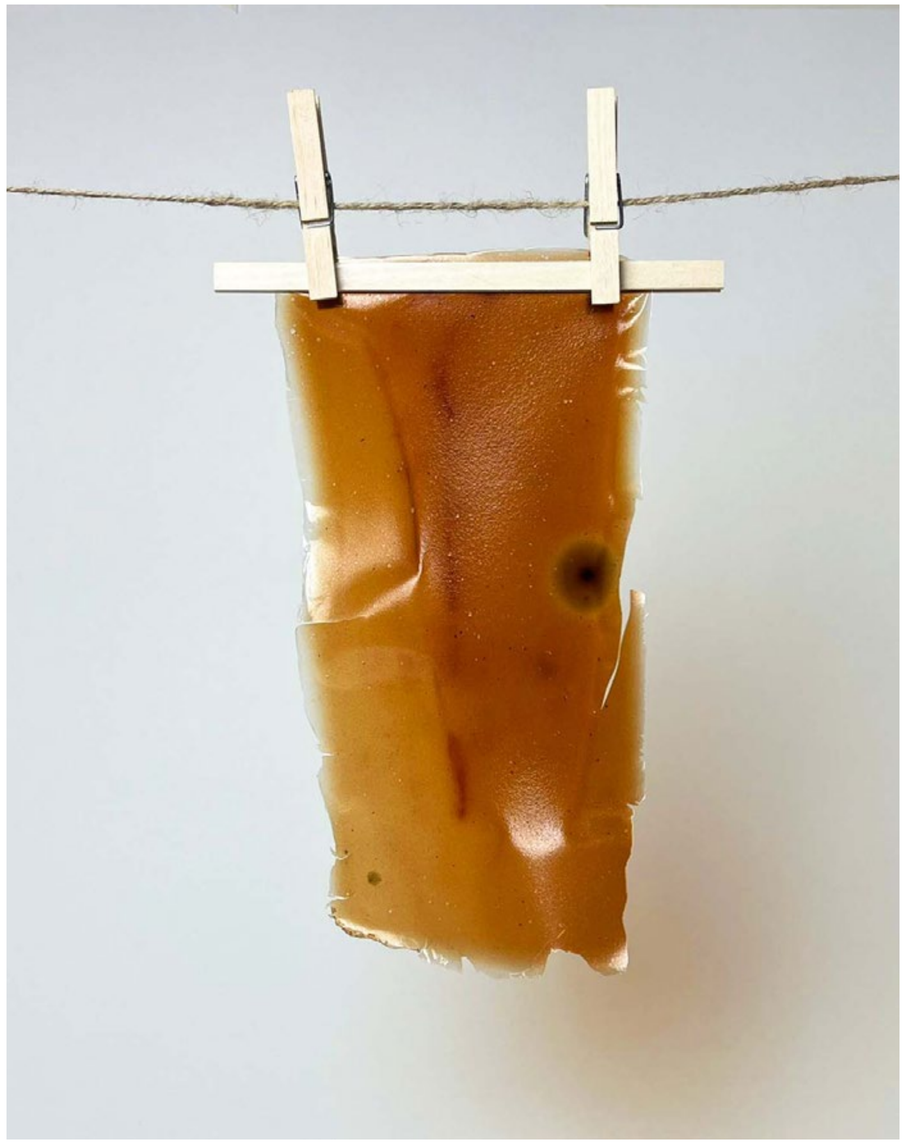
Thickness
Thin — *Thick*

Deformation
Flat — *Wrinkled*

Observations: sample is less flexible due to less glycerine, wrinkled a lot in the corners

No. 013

150ml seaweed dye / 3g agar / 1 g glycerine



Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Glossiness
Matte — *Glossy*

Colour Durability
Not durable — *Durable*

Transparency
Opaque — *Transparent*

Flexibility
Brittle — *Flexible*

Thickness
Thin — *Thick*

Deformation
Flat — *Wrinkled*

Observations: interesting amber colour, thick layer was poured, started to mold

No. 014

300 ml water / 6 g carrageenan / 6 ml glycerine / 1 g red seaweed flakes / 1 g kelp flakes

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Glossiness
Matte — *Glossy*

Colour Durability
Not durable — *Durable*

Transparency
Opaque — *Transparent*

Flexibility
Brittle — *Flexible*

Thickness
Thin — *Thick*

Deformation
Flat — *Wrinkled*

Observations: Sample was poured in a bigger mould. It was left to dry in the mould and as a result it got hard to separate it from it.

No. 015

150ml water / 3g carrageenan kappa / 3ml glycerine / 1g kelp flakes

Visual experience: Bad — Good
Texture: Rough — Smooth
Glossiness: Matte — Glossy
Colour Durability: Not durable — Durable
Transparency: Opaque — Transparent
Flexibility: Brittle — Flexible
Thickness: Thin — Thick
Deformation: Flat — Wrinkled

Observations: interesting tereazzo effect, the sample is translucent rather than transparent

No. 016

100ml water / 4g agar / 4ml glycerine / 5g kombu powder

Visual experience: Bad — Good
Texture: Rough — Smooth
Glossiness: Matte — Glossy
Colour Durability: Not durable — Durable
Transparency: Opaque — Transparent
Flexibility: Brittle — Flexible
Thickness: Thin — Thick
Deformation: Flat — Wrinkled

Observations: wrinkled and shrinked significantly while drying

No. 017

150ml water / 4g carrageenan kappa / 4ml glycerine / 1g green seaweed flakes

Visual experience
Bad — Good

Texture
Rough — Smooth

Glossiness
Matte — Glossy

Colour Durability
Not durable — Durable

Transparency
Opaque — Transparent

Flexibility
Brittle — Flexible

Thickness
Thin — Thick

Deformation
Flat — Wrinkled

Observations: this sample was left in the dehydrator to dry, difficult to seperate from the mould after it was dried.

No. 018

150m water / 4g agar / 4ml glycerine / 1g green seaweed flakes

Visual experience
Bad — Good

Texture
Rough — Smooth

Glossiness
Matte — Glossy

Colour Durability
Not durable — Durable

Transparency
Opaque — Transparent

Flexibility
Brittle — Flexible

Thickness
Thin — Thick

Deformation
Flat — Wrinkled

Observations: this sample was left in the dehyrator to dry but contrary to the carrageenan sample it was still easy to seperate from the mould. Great sample.

No. 019

150 ml water / 4 g agar / 4 ml glycerine / ~1 g astaxanthin

Visual experience
Bad — Good

Texture
Rough — Smooth

Glossiness
Matte — Glossy

Colour Durability
Not durable — Durable

Transparency
Opaque — Transparent

Flexibility
Brittle — Flexible

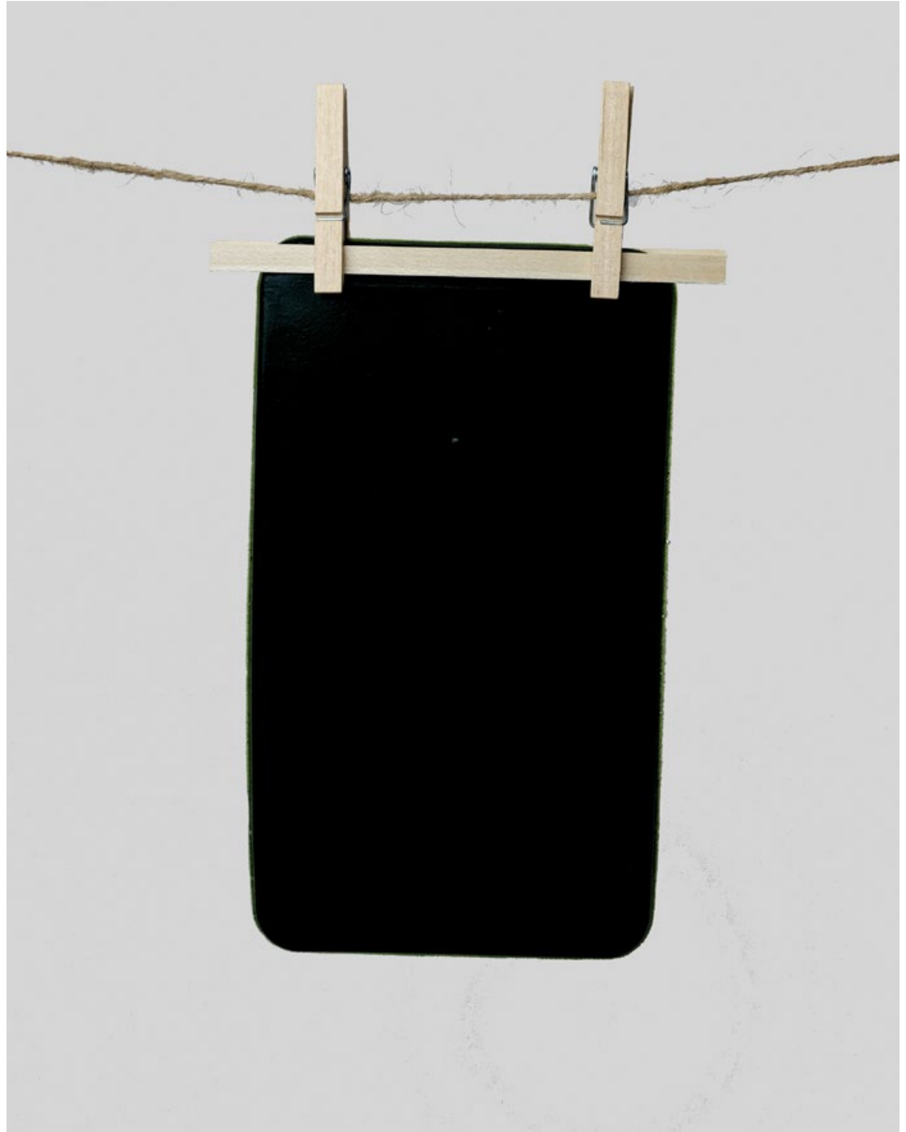
Thickness
Thin — Thick

Deformation
Flat — Wrinkled

Observations: Astaxanthin was mixed in from the start which resulted in the sample having an interesting red colour and being translucent

No. 020

150 ml water / 4 g agar / 4 ml glycerine / 2g green spirulina



Visual experience
Bad — Good

Texture
Rough — Smooth

Glossiness
Matte — Glossy

Colour Durability
Not durable — Durable

Transparency
Opaque — Transparent

Flexibility
Brittle — Flexible

Thickness
Thin — Thick

Deformation
Flat — Wrinkled

Observations: The sample turned out to be dark almost black colour. The sample got stuck in the mould while drying.

No. 021

150ml water / 4g agar / 4ml glycerine / 1g blue spirulina

Visual experience — *Bad* / *Good*

Texture — *Rough* / *Smooth*

Glossiness — *Matte* / *Glossy*

Colour Durability — *Not durable* / *Durable*

Transparency — *Opaque* / *Transparent*

Flexibility — *Brittle* / *Flexible*

Thickness — *Thin* / *Thick*

Deformation — *Flat* / *Wrinkled*

Observations: In contrast to green spirulina, blue spirulina foes not blend well in the mixture, which creates this speckled effect

No. 022

150ml water / 4g agar / 4g glycerine / eelgrass

Visual experience — *Bad* / *Good*

Texture — *Rough* / *Smooth*

Glossiness — *Matte* / *Glossy*

Colour Durability — *Not durable* / *Durable*

Transparency — *Opaque* / *Transparent*

Flexibility — *Brittle* / *Flexible*

Thickness — *Thin* / *Thick*

Deformation — *Flat* / *Wrinkled*

Observations: eelgrass as reinforcement made the bioplastic stronger

No. 023

150ml water / 4g agar / 4g glycerine / 2tbsp spirulina alginate caviar

Visual experience
Bad *Good*

Texture
Rough *Smooth*

Glossiness
Matte *Glossy*

Colour Durability
Not durable *Durable*

Transparency
Opaque *Transparent*

Flexibility
Brittle *Flexible*

Thickness
Thin *Thick*

Deformation
Flat *Wrinkled*

Observations: the spirulina alginate caviar fell out of the samples in some places, caviar should be left to dry out for a while before adding it to the sample.

No. 024

150ml water / 4g agar / 4g glycerine / spirulina alginate strings

Visual experience
Bad *Good*

Texture
Rough *Smooth*

Glossiness
Matte *Glossy*

Colour Durability
Not durable *Durable*

Transparency
Opaque *Transparent*

Flexibility
Brittle *Flexible*

Thickness
Thin *Thick*

Deformation
Flat *Wrinkled*

Observations: the spirulina alginate strings fell out of the samples in some places, they should be left to dry out for a while before adding it to the sample.

No. 025

150ml water / 4g agar / 4g glycerine / 2tbsp astaxanthin alginate caviar

Visual experience
Bad — Good

Texture
Rough — Smooth

Glossiness
Matte — Glossy

Colour Durability
Not durable — Durable

Transparency
Opaque — Transparent

Flexibility
Brittle — Flexible

Thickness
Thin — Thick

Deformation
Flat — Wrinkled

Observations: For this sample, the caviar was left to dry for a day before adding it to the mixture, which made the sample better

No. 026

200ml water / 4g agar / 4g glycerine / ~1 g spirulina

Visual experience
Bad — Good

Texture
Rough — Smooth

Glossiness
Matte — Glossy

Colour Durability
Not durable — Durable

Transparency
Opaque — Transparent

Flexibility
Brittle — Flexible

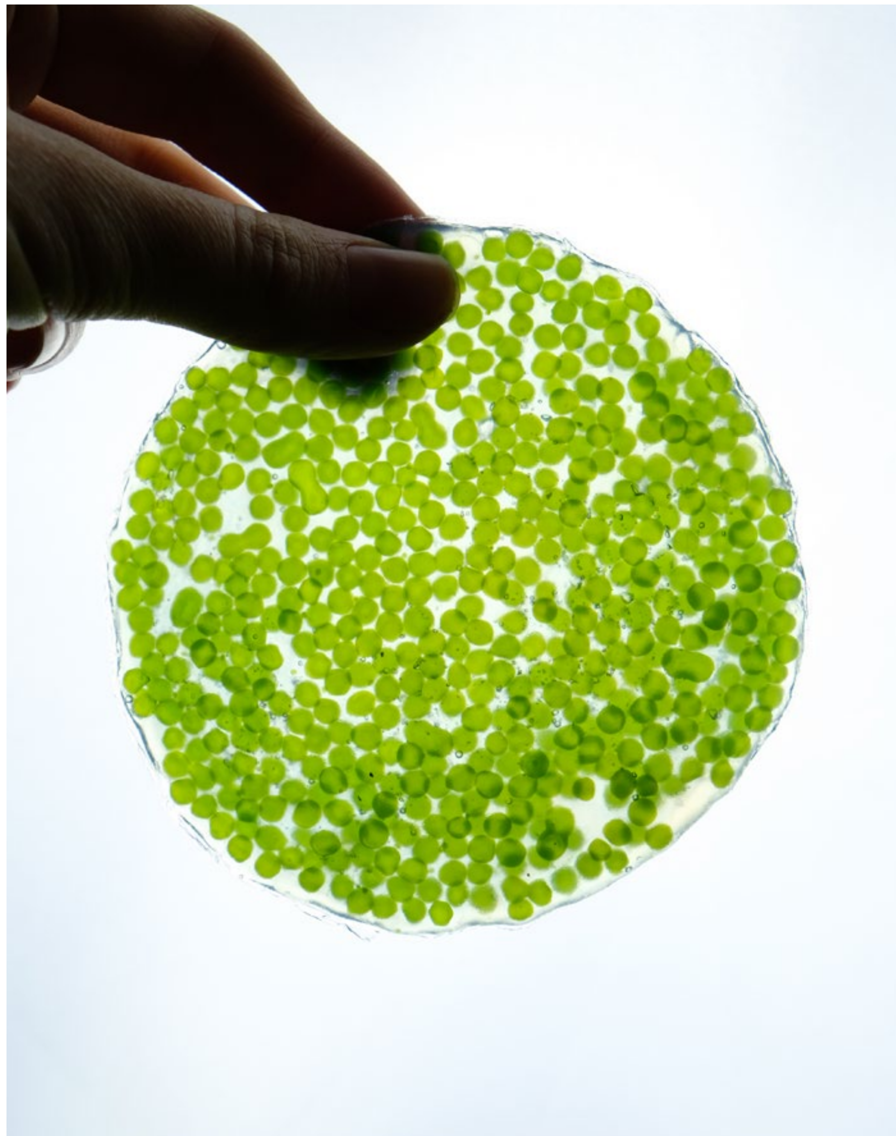
Thickness
Thin — Thick

Deformation
Flat — Wrinkled

Observations: Solution was divided in two pots and only one had spirulina added to it. After that both mixtures were poured into the mould which resulted in an creation of an interesting marbling pattern.

No. 027

3 tbsp spirulina alginate caviar / 50 g 2,5 % alginate solution



Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Glossiness
Matte — *Glossy*

Colour Durability
Not durable — *Durable*

Transparency
Opaque — *Transparent*

Flexibility
Brittle — *Flexible*

Thickness
Thin — *Thick*

Deformation
Flat — *Wrinkled*

Observations: The sample was sprayed with calcium chloride to harden.

40

SEACRETE

Evaluation of the experiments

The batch of seacrete samples was made to investigate possibilities of using them as a functional material that could be used on the outside of the building and would have good aesthetic values. Keeping these functions in mind samples were evaluated in six different criteria. The first three of the criteria concern aesthetic values of the samples and the last three investigate the technical possibilities of the created material. All of the samples were evaluated between one to four weeks after the making to ensure that they are completely dry and the color durability of the samples could be evaluated properly.

Visual Experience

This criteria evaluates how the material looks. The scale ranges from "bad" to "good" but in fact what is evaluated here is how well the material would look if applied in the building project. When judging "bad" or "good" what is taken into consideration is the shape of the sample, the color and the homogeneity of the material.

Texture

Texture refers both to visual and tactile experience of the sample. This criteria evaluates if the sample is "rough" or "smooth" when looked at and touched. What can influence the roughness of the sample are the ingredients used, the grain size of the oystershell powder and the additives.

Colour Durability

The evaluation for this particular criteria is made over time. The most visible changes can be seen after even 4 weeks from the sample making. Its is also noticeable that the color change issue mostly appears in the samples where color additives were used. If the sample was only colored as a result of the ingredients mixed (e.g. seaweed pigment transfered onto the sample creating a marble effect) it appears to be durable when it comes to coloration.

Strength

The strength criteria was created to help evaluate how fitting a certain sample could be as a part of facade element in a building. Because of lack of professional equipment to test how strong a certain material is this evaluation was based on estimations.

Flexibility

This criteria was created to evaluate technical possibilities of particular samples. Some of them turned out very brittle and hard and some more flexible. The ability of these samples to be flexible depends mostly on what kind of additive was used in the mixture. For example paper samples turned out more flexible than seashell samples.

Shrinkage

This criteria refers to how big the size difference is between the wet and dry sample. Some of the samples shrunk significantly while some stayed almost unchanged during the drying process. This depends largely on the additive but also on the amount of water used during the process of making the sample.

No. 101

150ml water / 3g agar / 3ml glycerine / 10g blended seaweed

Visual experience
Bad — Good

Texture
Rough — Smooth

Colour Durability
Not durable — Durable

Strength
Fragile — Strong

Flexibility
Brittle — Flexible

Shrinkage
Small — Big

Observations: the sample dried at room temperature, molded (should be dried in oven to prevent molding), large deformation but very hard material

No. 102

150ml water / 10g blended seaweed / 1g baking powder

Visual experience
Bad — Good

Texture
Rough — Smooth

Colour Durability
Not durable — Durable

Strength
Fragile — Strong

Flexibility
Brittle — Flexible

Shrinkage
Small — Big

Observations: the sample did not bind, extreme cracking

No. 103

150ml water / 5g agar / 5ml alginate solution / 3ml glycerine / 10g dried seaweed

Visual experience — Bad / Good

Texture — Rough / Smooth

Colour Durability — Not durable / Durable

Strength — Fragile / Strong

Flexibility — Brittle / Flexible

Shrinkage — Small / Big

Observations: the sample molded and cracked, unpleasant smell.

No. 104

40g blended seaweed / 20g recycled paper / 50ml alginate solution / water

Visual experience — Bad / Good

Texture — Rough / Smooth

Colour Durability — Not durable / Durable

Strength — Fragile / Strong

Flexibility — Brittle / Flexible

Shrinkage — Small / Big

Observations: took a long time to dry and deformed

No. 105

20g blended seaweed / 20g recycled paper / 50ml alginate solution / water

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Colour Durability
Not durable — *Durable*

Strength
Fragile — *Strong*

Flexibility
Brittle — *Flexible*

Shrinkage
Small — *Big*

Observations: took a long time to dry and deformed

No. 106

40g dried eelgrass / 20g recycled paper / 50ml alginate solution / water

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Colour Durability
Not durable — *Durable*

Strength
Fragile — *Strong*

Flexibility
Brittle — *Flexible*

Shrinkage
Small — *Big*

Observations: the sample bound, took long time to dry

No. 107

7g dried eelgrass / 20g alginate solution

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Colour Durability
Not durable — *Durable*

Strength
Fragile — *Strong*

Flexibility
Brittle — *Flexible*

Shrinkage
Small — *Big*

Observations: could be used as an OSB board if pressed under a hydraulic press

No. 108

70g boiled and blended kombu / 15g recycled paper / 20g alginate solution / 1g spirulina

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Colour Durability
Not durable — *Durable*

Strength
Fragile — *Strong*

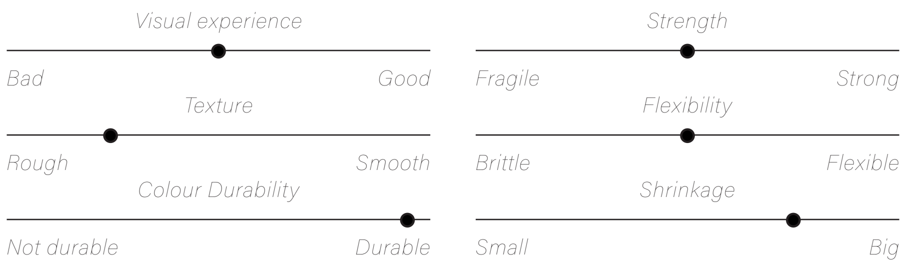
Flexibility
Brittle — *Flexible*

Shrinkage
Small — *Big*

Observations: sample was dried on a plastic form, bound very well, strong

No. 109

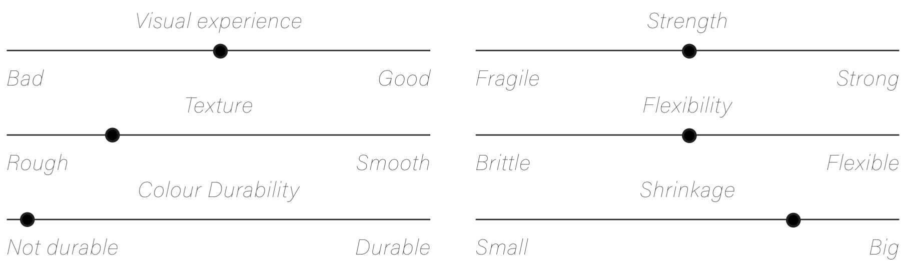
10g dried kelp powder / 10g recycled paper / 10g alginate solution (2.5%) / 1g spirulina



Observations: very light sample, strong smell

No. 110

10g dried kelp powder / 10g recycled paper / 10g alginate solution (2.5%) / 1g astaxanthin



Observations: very light sample, strong smell, the colour dissapeared after a few months

No. 111

60g oyster shell powder / 40ml alginate solution (2.5%)

Visual experience
Bad *Good*
Texture
Rough *Smooth*
Colour Durability
Not durable *Durable*

Strength
Fragile *Strong*
Flexibility
Brittle *Flexible*
Shrinkage
Small *Big*

Observations: dried in the oven at 40°C for 12 hours, bound quite well and is quite strong

No. 112

40g oyster shell powder / 10g seaweed / 40ml alginate solution (2.5%)

Visual experience
Bad *Good*
Texture
Rough *Smooth*
Colour Durability
Not durable *Durable*

Strength
Fragile *Strong*
Flexibility
Brittle *Flexible*
Shrinkage
Small *Big*

Observations: dried in the oven at 40°C for 12 hours, seaweed coloured the sample nicely

No. 113

60g oyster shell powder / seaweed / 40ml alginate solution (2.5%)

Visual experience

Bad *Good*

Texture

Rough *Smooth*

Colour Durability

Not durable *Durable*

Strength

Fragile *Strong*

Flexibility

Brittle *Flexible*

Shrinkage

Small *Big*

Observations: dried in the oven at 40°C for 12 hours, seaweed created an interesting pattern on the sample.

No. 114

60g oyster shell powder / 3g seaweed / 40ml alginate solution (2.5%)

Visual experience

Bad *Good*

Texture

Rough *Smooth*

Colour Durability

Not durable *Durable*

Strength

Fragile *Strong*

Flexibility

Brittle *Flexible*

Shrinkage

Small *Big*

Observations: dried in the oven at 40°C for 12 hours, interesting pattern was created.

No. 115

45g oyster shells powder / 15g bladderwrack powder / 60ml alginate solution (2.5%)

Visual experience: Bad — Good
Texture: Rough — Smooth
Colour Durability: Not durable — Durable
Strength: Fragile — Strong
Flexibility: Brittle — Flexible
Shrinkage: Small — Big

Observations: The sample was fragile and did not bind well. The dried seaweed powder in the sample expanded and caused cracks in the material.

No. 116

30g oyster shells powder / 30g bladderwrack powder / 60ml alginate solution (2.5%)

Visual experience: Bad — Good
Texture: Rough — Smooth
Colour Durability: Not durable — Durable
Strength: Fragile — Strong
Flexibility: Brittle — Flexible
Shrinkage: Small — Big

Observations: The sample was fragile and did not bind well. The dried seaweed powder in the sample expanded and caused cracks in the material.

No. 117

60g oyster shell powder / carrageenan / astaxanthin

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Colour Durability
Not durable — *Durable*

Strength
Fragile — *Strong*

Flexibility
Brittle — *Flexible*

Shrinkage
Small — *Big*

Observations: Astaxanthin lost its colour after drying, carrageenan was hard to control while pouring into the mould.

No. 118

90g oystershell powder / 60ml alginate solution (2.5%) / 1g spirulina

Visual experience
Bad — *Good*

Texture
Rough — *Smooth*

Colour Durability
Not durable — *Durable*

Strength
Fragile — *Strong*

Flexibility
Brittle — *Flexible*

Shrinkage
Small — *Big*

Observations: Sample became slightly coloured with spirulina.

KELP LEATHER

Evaluation of the experiments

The experiments on kelp leather were made to investigate possibilities of using this material on the outer wall of a building. The goal was to create cladding material that could be used as a facade. Keeping this in mind, samples were evaluated with four different criteria. The first two criteria concern aesthetic values of the samples and remaining two investigate the technical possibilities of the created material.

Flexibility

This criteria was created to evaluate technical possibilities of particular samples. Some of them turned out very brittle and hard and some more flexible. This was one of the most important criteria because the goal of these exper iments was to create a flexible material.

Glossiness

This criteria refers to the reflective abilities of the material. The scale ranges between "glossy" and "matte". The experiments vary when it comes to reflectiveness depending on additives used on the surface of kelp pieces.

Strength

Strength criteria was created to help with evaluation how fitting a certain sample could be as an outer facade. It was important to make sure that the pieces of kelp will not for example tear apart when placed on a wall. Because of lack of professional equipment to test how strong a certain material is this evaluation was based on estimations.

Deformation

While drying some of the samples kept their flat shape while others became quite deformed. This depends largely on the additives used. For example using oil resulted in the sample becoming wrinkled while using glycerine did not influence the shape of the kelp at all.

No. 201

oil

Flexibility: Brittle — Flexible

Strength: Fragile — Strong

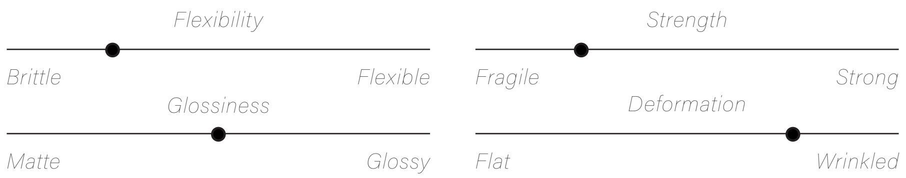
Glossiness: Matte — Glossy

Deformation: Flat — Wrinkled

Observations: Sample hardened and can easily be crushed.

No. 202

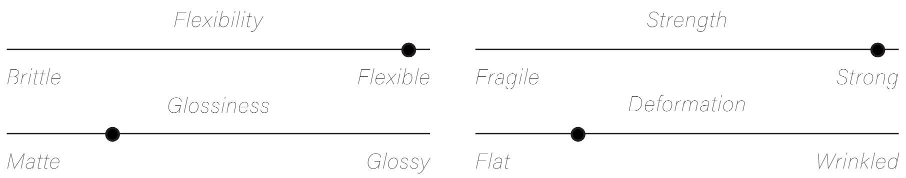
vinegar / oil



Observations: Strong smell from vinegar, sample hardened

No. 203

glycerine



Observations: Flexible sample. Two layers of glycerine needed. Will remain flexible even after soaked in water and dried again. More tests are needed to establish how it will react to water over a longer time.

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