Figure 1: Presentation of a final module.

BIOTILES: A SUSTAINABLE INTERIOR WALL PANEL

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Abstract

The present project proposes the use of materials of natural origin in additive manufacturing, with a view to producing new decorative wall tiles. The historical evolution of the Vimaranense house, tells us a narrative that even today is kept intact by the preservation of its memory. It is common to see slate tiles in the city of Guimarães for gable linings, or additions to the roofs of buildings, such as chimneys, skylights, and rooflights. The soletos' or fish scales, are tiles of small dimensions and distinctive shapes, obtained from slate rocks.

Introduction

Contemporary architecture has been seeking new construction practices taking advantage of sustainable' green' materials. The excessive extraction of natural resources and the use of polluting equipment is causing a considerable environmental impact on planet earth. It is necessary to reduce the extraction of these resources and select materials of natural origin and low cost to obtain.

The presented project has the function of reinterpreting the soletos used in the housing construction of Guimarães, replacing the slate rock for materials of natural origin, reusable and biodegradable. The display consists of a set of individual modules, with the same geometry and different finishes, produced with cellulose and chitin – two natural biopolymers very abundant in our planet. Taking advantage of digital design and additive manufacturing techniques, a dynamic pattern was developed with different densities, providing a three-dimensional effect. Individually the modules are all distinct, when assembled they form a continuous pattern.

SEAfood waste

The fishing industry produces tons of seafood waste every year, resulting in large losses due to poor management of marine resources. Shellfish waste, such as seafood shells, fish scales, squid skins and fungal cells, are rich in chitin – the second most abundant natural biopolymer on the planet [3]. Chitin is a monomer structurally similar to cellulose (the most abundant polymer on the planet) and is obtained by a set of chemical processes – demineralisation, deproteinization – from shellfish waste. Chitosan, a polymer also of natural origin, is a derivative of chitin. The application of this biopolymer has led to a high search in the production of new components because it is a natural, non-toxic, low-cost, renewable, sustainable and biodegradable material. [1] The MIT has developed

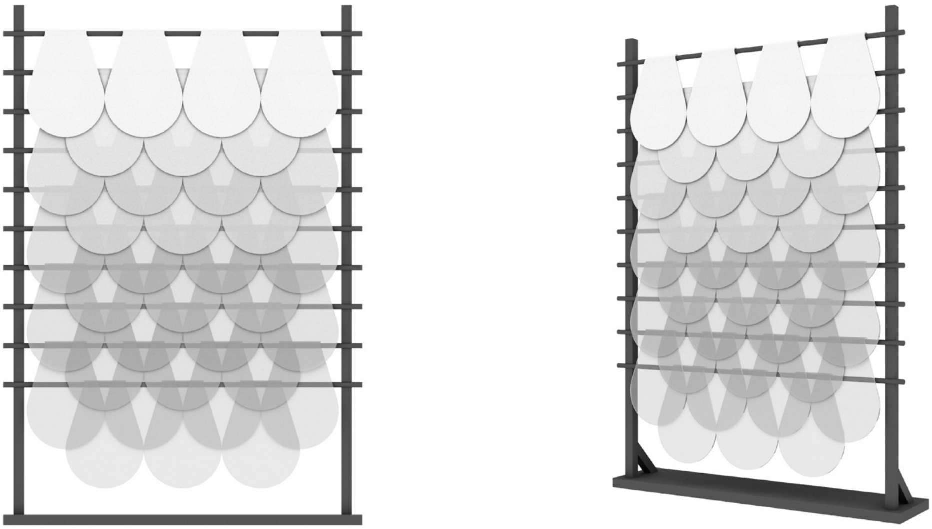


Figure 2: Three-dimensional presentation of the designed exhibitor with the respective modules. Front view (left). Axonometric view (right).

a prototype 'Aquahoja Pavillion' which consists of coating a metal structure using a mixture based on materials of natural origin –cellulose and chitin – for the additive manufacture of highly customised leathers. [5-7] At the University of Singapore, a 100cm high column was designed, using materials of natural origin – cellulose and chitin – inspired by the biological forms of nature. [4] The Shellworks group has developed a set of machines for chitin extraction. The machine prototypes designed have different functions, from the pure extraction of the material, to the transformation of the biopolymer into a marketable, highly sustainable, biodegradable and recyclable product.

BioDESIGN: Exhibitor digital fabrication

As a way of transforming the waste heavily found in the fishing industry and developing an architectural system, a vertical exhibition was proposed, composed of a group of individual modules, the BioTILES. These result from a reinterpretation of the old 'soletos' used in Portuguese historic buildings and aim to develop new decorative wall coverings. The 'soletos' or fish scales, are tiles of small dimensions and distinct shapes, obtained from slate rocks. with thin thicknesses, they overlap each other, fixed on a wooden lath with metal elements.

Developed using three-dimensional modelling software, Rhinoceros and Grasshopper, the proposed exhibition is composed of 35 individual modules, with different shades, textures and shapes (Figure 2). Like the 'soletos', the modules were designed taking into account the shape and fixing system. The geometry was inspired by the silhouette of the sea shells as a representation of nature and the sea.

The exhibitor is composed of a vertical structure – 1000mm height by 700mm width - and 10 horizontal profiles to support the modules and block it. The fixing system consists of the AM (Additive Manufacturing) of a semi-circular piece with a front open grid geometry (Figure 3). The grid functions as an aggregation system, in which the material surrounds the geometry, soaking it up, creating a strong link between them.

Designed the exhibitor and taking advantage of the AM technique PEM – Paste Extrusion Modelling – a pattern was developed to be printed in the modules. The pattern has the function to confer resistance to the module.

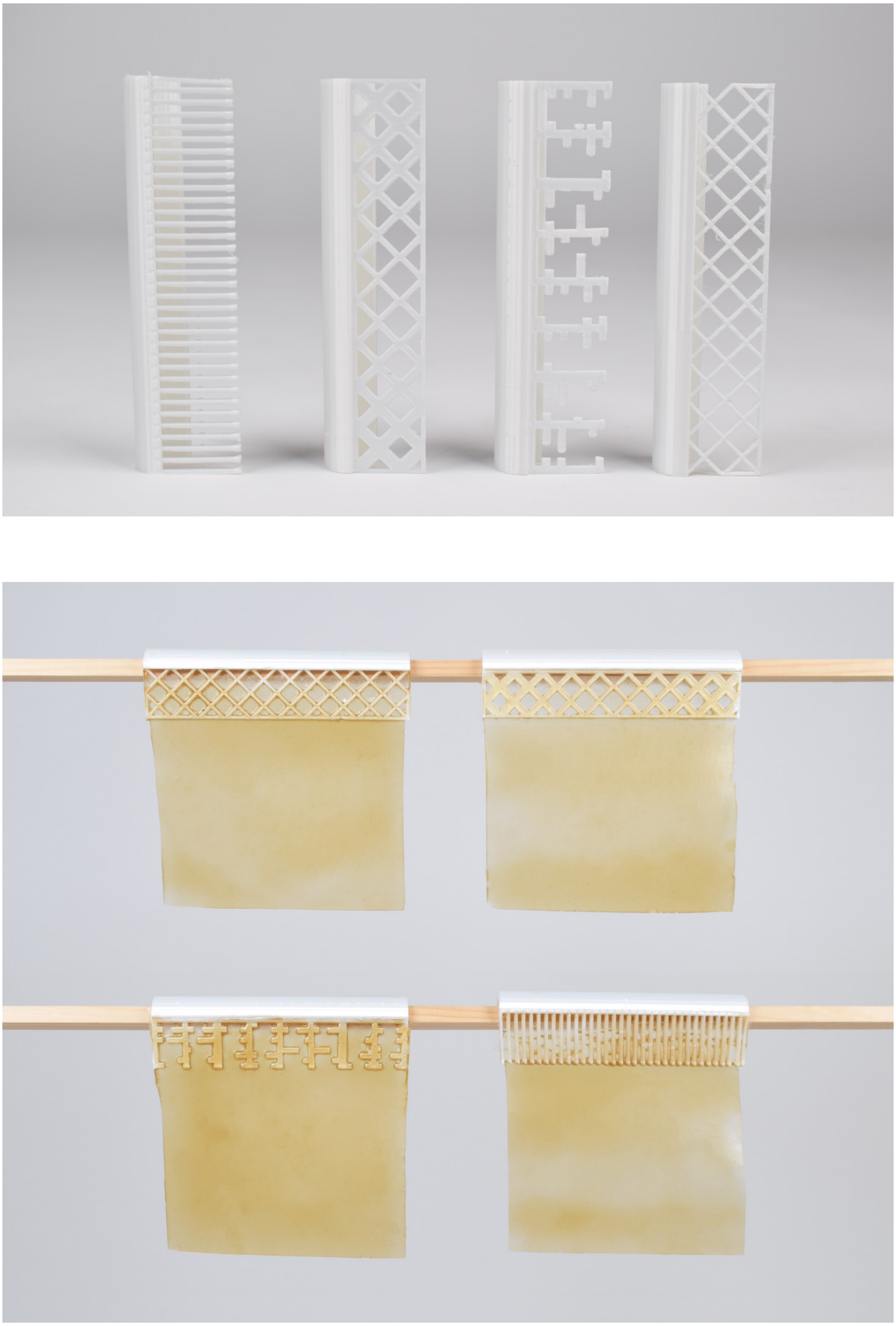
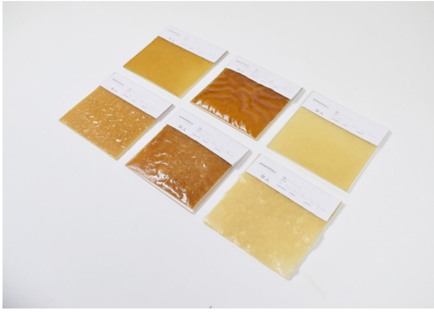


Figure 3: Presentation of the proposed fixing system. Proposal of the designed system (up). Proposed system embedded in the mixture (down).



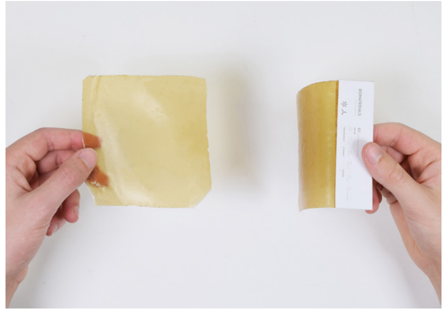


Figure 4: Different material finishes (left). Behaviour of the material with glycerine (right).

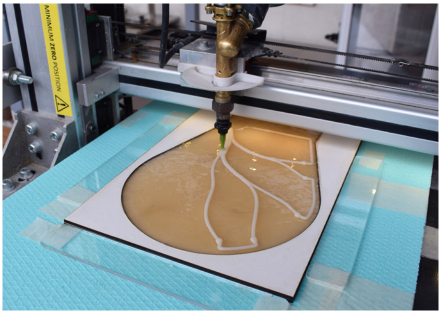
BioTILES fabrication

(1) Material Preparation

The material preparation consists of a combination of 80%-90% water (v/v), 4%-8% starch (w/v), 4% glycerine (v/v) and according to the final properties required, 0%-12% cellulose (w/v) is added. After homogenisation of the components, the mixture is heated until it forms a viscous pulp – a water-based hydrogel. Then, as the temperature decreases, 4%-8% chitosan (w/v) and 2%-4% acetic acid (v/v) are added and the material is ready to be used. [3]

(2) Material Properties

The addition of cellulose during the preparation of the material is related to the characteristics intended to be obtained in the final object. The function of this material is to increase the strength, rigidity and durability of the final product. The addition of glycerine is intended to give flexibility to the material, the higher the proportion, more flexible is the product. The chitosan and then the addition of acetic acid aims to transform the water-based hydrogel into a fully viscous and homogeneous pulp. [3] In addition, it has the function of giving colour to the final product, the higher the proportion of chitosan added, the more colourful is the final tone.



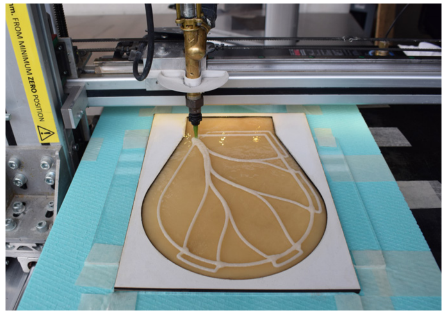


Figure 5: Printing a module using the PEM technique (Paste Extrusion Modelling).

(3) Fabrication

The manufacture of the exhibitor was divided into three work phases:

(1) Manufacture of the vertical and horizontal structure;
(2) Manufacture of the fixing system;
(3) Manufacture of the individual modules.

In a first step, taking into account the previously designed model, the support structure for the individual modules was produced. The structure is composed of 2 solid pine beams (20mmx20mmx1000mm), 10 solid pine slats (10mm (radius)x700mm) and a base in solid pine wood (1040mmx200mmx20mm).

In a second phase of the work, taking advantage of AM techniques, namely FDM - Fused Deposition Modelling - a set of open geometry patterns was studied and the one with the highest capacity to support external forces was adopted.

Once the structure and the fixing system had been developed, in a third phase the production of the 35 individual modules that make up the exhibitor started. The production of the components resulted in the combination of two AM techniques – Moulding and PEM. First the fixing was placed on the edge of the previously made mould. Then, the fluid mixture was introduced inside the mould until the empty space was filled, holding on to the open geometry grid (fixing soaked in the mixture). Finally, using the Lutum® 2.0 Mini printer, the developed pattern was printed on the previously filled mixture.

For the manufacture of the components, two types of mixture were used:

(1) Mixture introduced into the mould, a fluid mixture with a high level of flexibility (water + starch + glycerin + chitosan).
(2) Mixture printed on the mould, a fluid mixture with a high level of resistance (water + starch + cellulose + chitosan).

The combination of these two mixtures allows the module to assume different shapes, with a degree of resistance to possible breaks or tears

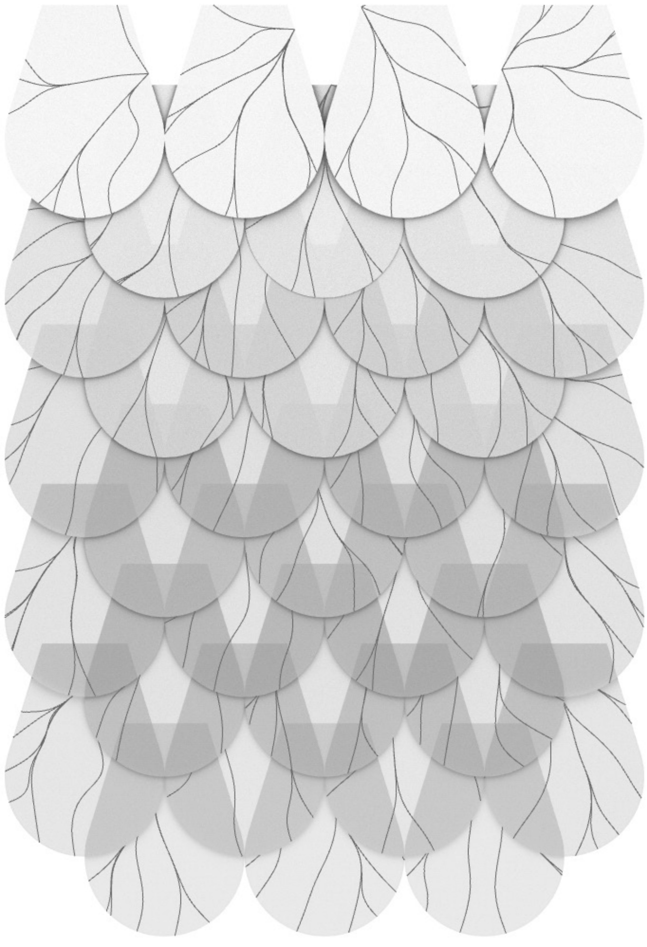


Figure 6: Proposal of the pattern for each module.

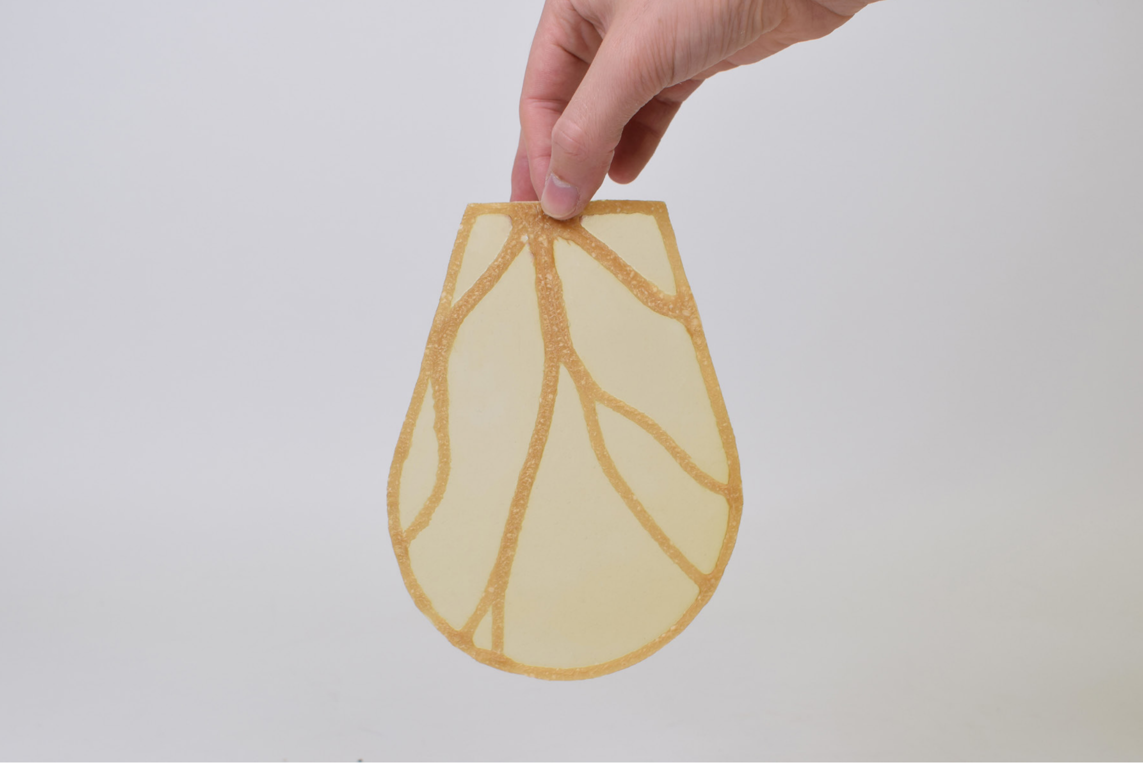


Figure 7: Presentation of a final module.

Conclusion

Motivated by the need to find a new strategy to reduce the continuous accumulation of seafood waste in the fishing industry, we have developed a set of natural, non-toxic, low-cost, renewable, sustainable and biodegradable mixtures. With the use of natural biopolymers, we have developed a new architectural application, the BioTILES, fully customisable. These pieces are a reinterpretation of the history of Vimaranense architecture – the famous Portuguese slate ‚soletos’ used in buildings in the historic centre of cities in northern Portugal, namely Guimarães and Porto. The alteration of the proportions of the different mixtures produced, confer different mechanical, physical and aesthetic behaviours. The proportion of chitosan strongly influences the shade of the material; cellulose considerably decreases the transparency; and glycerine provides flexibility and resistance to possible breaks. When combined in different proportions they give the final product different solutions. The exhibitor is composed of a set of options previously thought out, with the aim of creating optical illusions to the observers, due to the differences in colour and texture of the material.

Acknowledgements

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