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The Mechanics of Bacterial Cellulose:
Form-finding in bio-composite structures

Introduction

This poster follows the completion of an undergraduate research award supervised by Dr. Mercedes Garcia-Holguera in the Faculty of Architecture. Dr. Garcia-Holguera's research follows a transdisciplinary approach to environmental building science that is inspired by nature's principles, as described in biomimicry and biomimetic design theories.

Biomimicry is a new science that emulates nature's successful models, structures, and systems in human constructs. Facing detrimental environmental damage due to humanity's continuous need for materials, a global transition from a linear to a circular economy is needed. As a part of a possible solution, cultivated building biomaterials could emerge from the construction and design industry. The current research at the BIOM_Lab works within these principles, exploring ways to advance architectural research. The research thus far has been focused on the growth and cultivation of biomaterials, namely bacterial cellulose and mycelium-based materials, thoughtfully exploring ways to implement their innovative material properties in architecture and design. Bacterial cellulose is a biofilm grown at the surface of a culture medium by a bacteria. This poster will describe research findings and observations made on the biomaterial's different mechanical properties through tensile strength explorations, weaving and joinery techniques, and temporary form-finding structures.

Tensile strength test

Made of fiberglass rebar framing, multi-layered bacterial cellulose sheets, and woven bacterial cellulose strands, a test apparatus has been devised to explore the tensile properties of bacterial cellulose (Fig.4.) Serving as a surface for varying loads (Fig.1), the apparatus' surface was divided into two sections: layered bacterial cellulose sheets and woven bacterial cellulose. The division was done to compare how the act of two separate joinery techniques, layering and weaving, may serve as an additional reinforcement to the tensile strength of bacterial cellulose as a material.

The first sector composed of three different layering techniques: (1) single-layered, (2) double-layered, and (3) six-layered. Each strand were made by manually layering cut wet bacterial cellulose sheets and air drying them (Fig.2.) According to observations of the test, layering may play a role in the reinforcement of the bacterial cellulose' strength; as the more layers there were, the less deformation of bacterial cellulose sheets took place after adding the loads. Additionally the layered sheets were able to retain its new shape, illustrating the potential plastic behavior of the biomaterial.

The second sector is composed of a woven bacterial cellulose surface (Fig.3.) Using a braiding technique, three sub-strands of air-dried, twisted bacterial cellulose sheets were integrated to create the final woven surface. Similar to the layered bacterial cellulose sheets, the woven surface also showed an irreversible deformation after loads had been added; another manifestation of the plastic behavior of bacterial cellulose.

Form-finding structures

One of our research's interest was to realize a living architectural membrane for future explorations and applications of living matter in architecture and design. Our overarching design goal was to assess whether bacterial cellulose could replace or enhance today's conventional tensile membrane structures.

As an initial explorative activity, novel hand-modeling systems and material manipulation were integrated to produce erect three-dimensional bacterial cellulose structures (Fig.5.) Air suspension and oxidation were two methods that were vital to this process. Suspended dry over a galvanized steel mesh, the inverted concave bacterial cellulose forms changed appearance, turning into a darkened, brittle form with enhanced structural stability.

Furthermore, folded bacterial cellulose structures were also explored. This was achieved through the folding of semi-air dried bacterial cellulose sheets which are then fully dried in a convectional oven. These forms (Fig.6) were able to retain their new, folded shape after the drying process.

Conclusion

This research composed of a wide exploration of potentialities concerning bacterial cellulose in different forms. Reflecting on observations and hypothesis made from our initial explorations, the expansion of bacterial cellulose's realm towards architecture and design is ultimately positive. With the aid of literature research, its strength in comparison to conventional membrane materials can be comparable. However, as this was an initial explorative process, there are more possibilities to be examined. There is also broad margin of optimization to be carried out with the found results and future material tests.

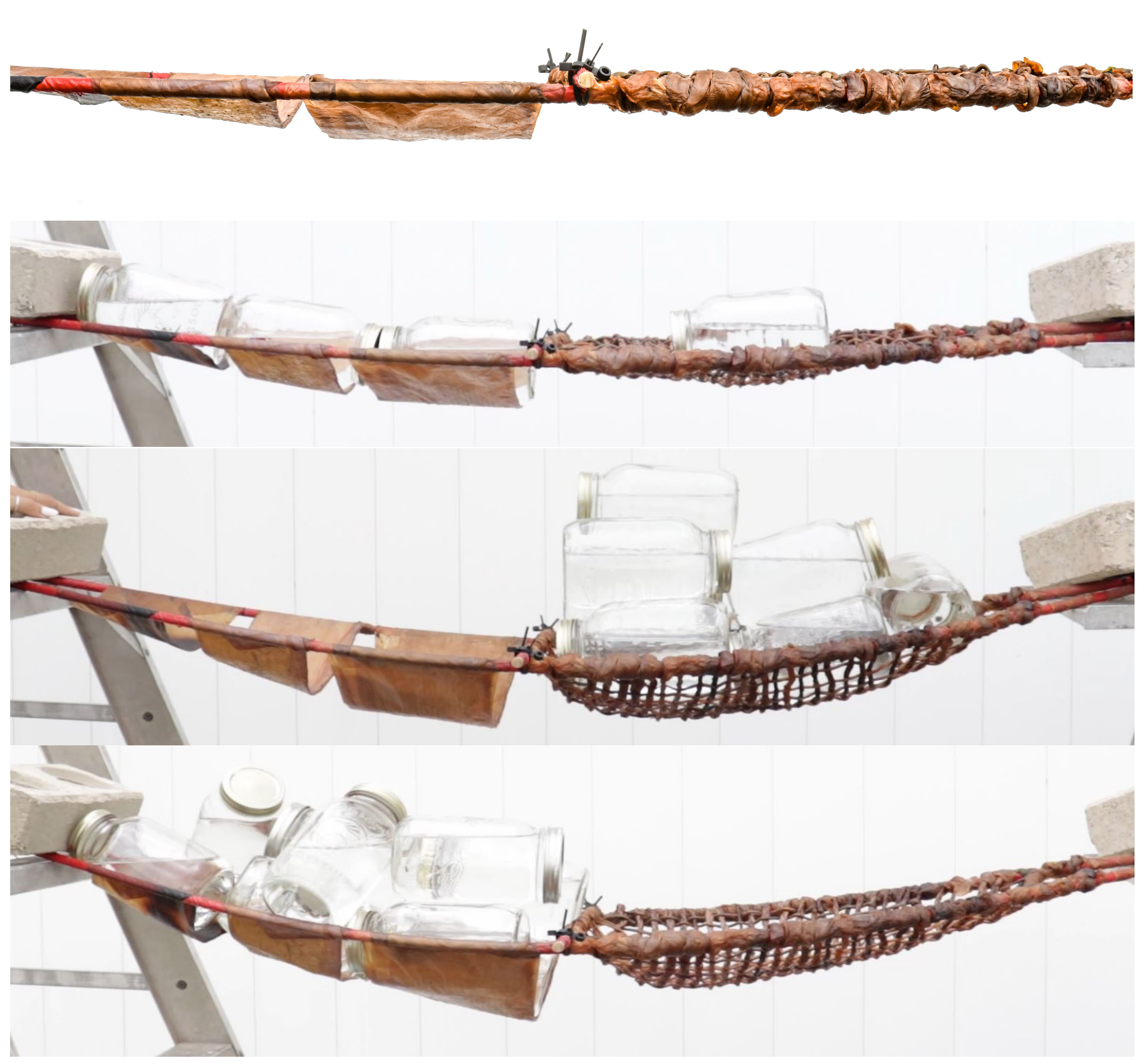

Fig.1 test for tensile strength

Fig.2 layered bacterial cellulose sheets

Fig.3 delicately woven bacterial cellulose surface

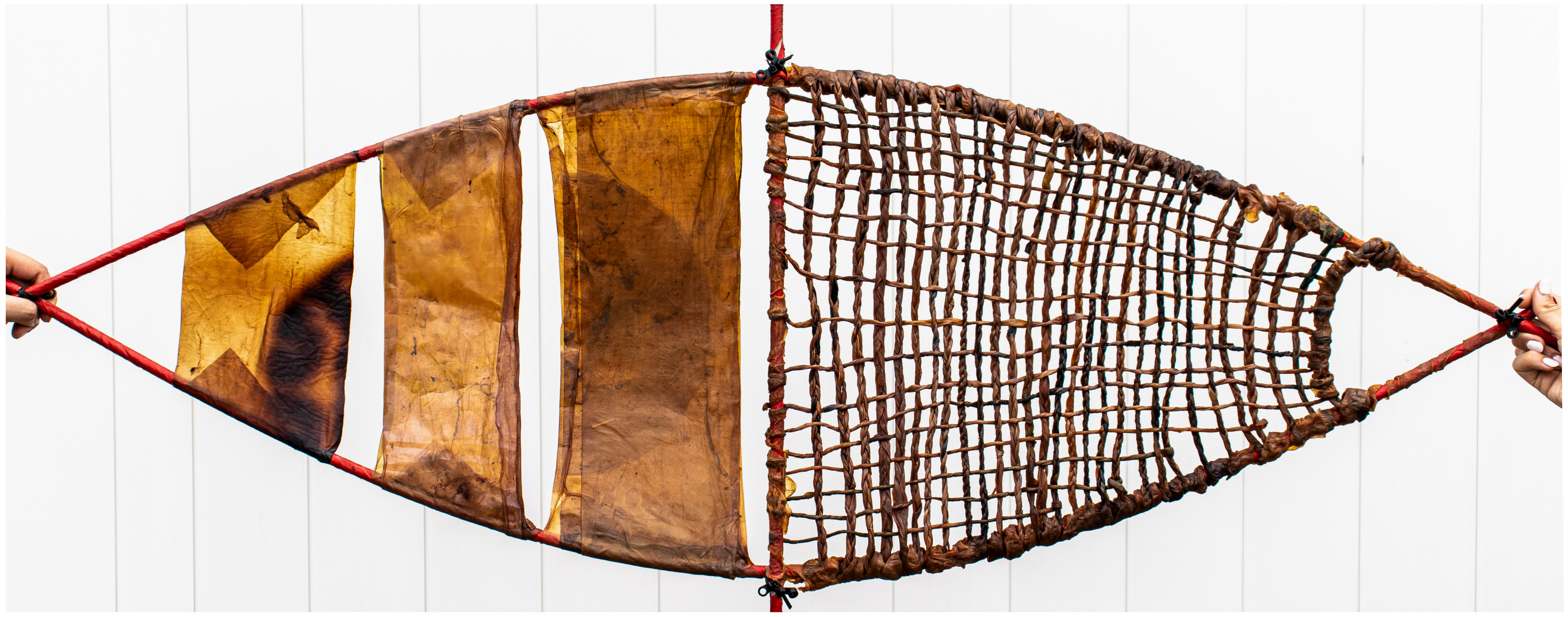

Fig.4 test apparatus

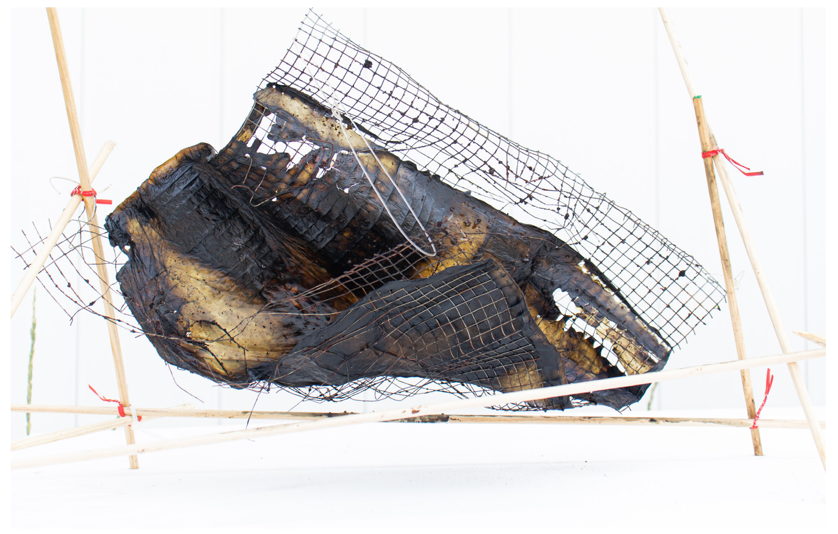

Fig.5 iterations of three-dimensional bacterial cellulose structures

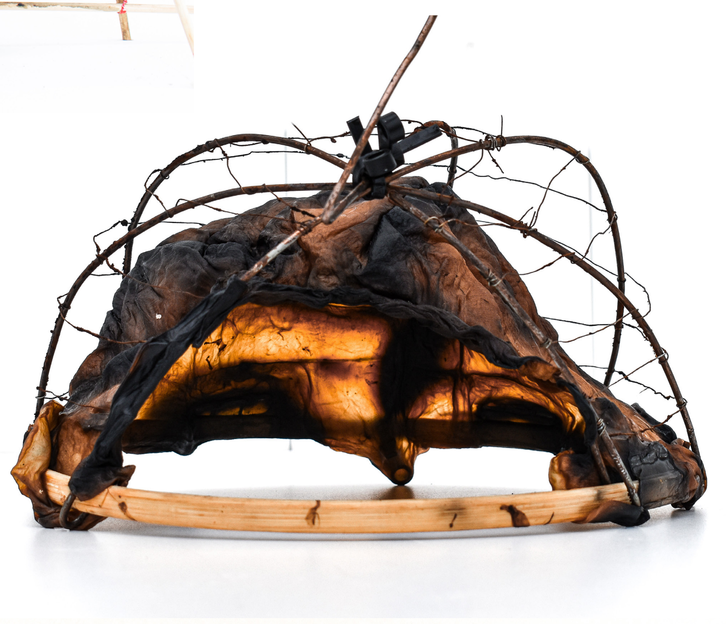

Fig.6 folded bacterial cellulose form