Responsiveness Based Material – [a] Passive Shading Control System

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ABSTRACT: During the last decades Architecture has been looking to its basic principles, finding in nature a natural and obvious inspiration. Materials and environment have been playing an important and essential role in this process. Recovering the ideals of the 1950's intellectually movement *Performative Turn*, performance-oriented design finds its fundaments on the understanding that architecture unfold their performative capacity by absorbing the complexity conditions and processes. Following this premise, architecture and environment are simultaneously set at a spatial, material and temporal level.
The following article has the goal to describe a methodology to find the material and environmental driven parameters to be considered in the design and construction of a passive shading system. This research aims to develop a universal parametric definition, based on cork material and environmental essential and determinant driven parameters that could enable us to design a totally personalized passive shading system to any location and time.

1 INTRODUCTION

Throughout the nineteenth century, human constructions relied on available/raw materials inertia for thermal regulation - buildings had thick walls and small narrow windows, enabling us to sustain the heat in the interior of the spaces during the winter, and protecting us from the intensive heat during the summer. Narrow windows helped us controlling the ventilation, minimizing/optimizing thermal behavior in the interior of the spaces according with uses and needs. In the twentieth century, advancements in insulation assemblies and composites of materials create possibilities for floor/ceiling walls with narrow steel frames - and mass production of these assemblies enables the pervasive reliance by humans of artificial air ventilation in the interior of the buildings and structures.

At this point of the 21st century, architecture and design find concepts and development, through layers of complementary information including those concerning constraints and criteria for the design of buildings envelopes - often constituted of assemblies of interrelated/responsive parts among each other with and with surrounding environment. Often in these building envelopes, form, material and structure are expressed and worked as distinct components from the same body, working independently from each other. However in nature there is no such distinction. There is no natural body or system, where structure is independent from material, or where material works independently from form, or even form independent from structure. In nature, bodies emerged as interrelated systems, with no assemblies or parts. The natural body is at once structure, form and material.

1.1 *Related work*

In recent years, new strategies for design and techniques for making materials and large constructions have emerged, based on biological models of the processes by which natural material forms are produced. Biological organisms have evolved multiple variations of form that should not be thought of as separate from their structure and material properties. Structural and informational forces collaborate to create what is ultimately a material, and then what we call form - these processes are very difficult to completely analyze and final natural bodies nearly impossible to be reproduced through the same growth methodology they were 'produced'. The self-organization of biological material systems is a dynamic process that occurs over time and produces the capacity for inducing change in the order and structure of a system, modifying its behavior and performance (Kauffman, 1993).

Passive systems - such as those observed in forms for feedback in nature between structural forces and form - create new questions and potentials to rethink architectural systems and bodies.

One example of this is the shading system Bloom, developed by the Dosu Studio 2012. Bloom is a bi-metal structure installation that reacts to heat, generating increasing or decreasing openings in a pattern, enabling a shading system to adapt to its environment. The keygen was a crucial part of understanding the material, its behavior conditions and characteristics, enabling a clearly development of the pattern behavior and performance.

Other iconic experience, in 2013, is the 'The Hygroscopic Envelop Prototype' from Achim Mengues based on a structural responsive and hygroscopic system. This system consists of a structural surface composed of several regions sensitive to local humidity concentration moving and adapting to climate change. More than finding architectural surfaces as solutions Menges "form follows performance" strategy mixes appearance and organization of patterned skins and structures in nature, enabling to explore materials behaviors and effects - biomimetics and biomimicry (Kolarevic and Klinger, 2008).

1.2 *Purpose and project*

In order to design a periodic shading control structure, mutable and (re)adaptable to a specific external environment and context, a customized definition is produced, parametrically reconfigurable, allowing for a total adaptation to external inputs and environmental data. The main focus of this research is the knowledge of material properties and performative responsiveness within the scope of some specific morphological conditions and environmental exposure. While keeping performative and responsive issues as digital layers, all the data is considered in the digital and virtual plane, being tested during the design process. This methodology aims to contribute to solve site-specific conditions and constraints.

2 OBJECTIVES

2.1 *General scope*

This paper presents an ongoing research focused in develop a passive shading control system, using parametric methodologies based material and environmental knowledge. The results are informed by design decisions based on contextual factors and consequently we are interested in stablish a parameter-driven methodology.

2.2 *Main goal*

The main goal defined, for this investigation stage, was to develop a parametric environmental system that could balance a multi-functioning driver parameter. The fundamental hypothesis supporting this system find its basis in the natural behavior of the applied materials (Cork and Metal), as well as in its internal and external exchange of data and environmental inputs. Inspired by natural physical elements, the target is to develop a parametric definition that expresses a shading control system that respond and adapts to a pre-determined environment, with specific characteristics, functions and to its inhabitants occupancy.

3 METHODOLOGY

The methodology (being) used to develop the passive shading system encompass three stages.

Stage 01: Material driven-parameters – Aims to find and describe through several material experiences and physical essays the most relevant and dominant material parameters that could influence the system.

The Stage 02: System – Form, structure, material – aims to point at two possible paths to achieve the shading system, explaining pattern decisions and some assembly considerations. The Stage 03: Integration design/Environmental analysis exposes the most relevant design parameters and design tools that are being used during the form-finding process.

3.1 *Stage 01: Material driven-parameters*

Conducting a material base investigation it's essential to understand the material characteristics and properties.

Cork it's a natural anisotropic material. 100% renewable, 100% organic, with excellent acoustic and thermal behavior. Cork is used and applied in several types of product and contexts - since insulation construction panels to umbrellas textiles. There are mainly three types of "cork": (a) The first one is the cork as a raw material – mainly used in the stoppers industry. (b) The second type of cork products, still 100% natural are expanded agglomerate – produced from the waste of all types of cork transformations. In this case the cork is granulated, heated and compacted in an autoclave at 350º degrees. This process inputs more than 3X the grain size and releases the suberin from the cork cells enabling the natural aggregation of the grains and the compaction of the material. (c) Cork agglomerated possibly the most used and known sub cork product. Contrary to the expanded agglomerate in the cork agglomerate the grain are not expanded, and the product conserve the natural cork color. There are several densities defined by the grain size and quantity. Grains could be mixed with resins, pigments, rubber and other aggregates.

The selected products for our research pilot prototypes were the expanded agglomerate cork – MD (Medium density) and HD (High density) - and agglomerate cork samples. Three different types of grain between 0,5mm to 25mm, and with a reference of self-weight of 300kg to 470kg/m3 – all high density.

3.1.1 *Cork design boundaries*

Knowing the anisotropic and cellular characteristics of the cork raw material, we could easily identify and understand several cork behavior and properties, such as lightness, compressibility, flexibility, expansion and so on. In a way to potentiate distortion and higher flexion cork cell microstructures were brought to board scale.

Four patterns were developed based on cork microcellular observation (Figure 2). Using as a primary structure the radial section, also known as the ‘honeycomb’ (Figure 1) parametric patterns were defined using as primary inputs the characteristics of the material: (1) Structural integrity and average number of the grain size (in the several boards) conditioning the scale of the patterns; (2) pattern equilibrium, properties and equilibrium based cork radial section.

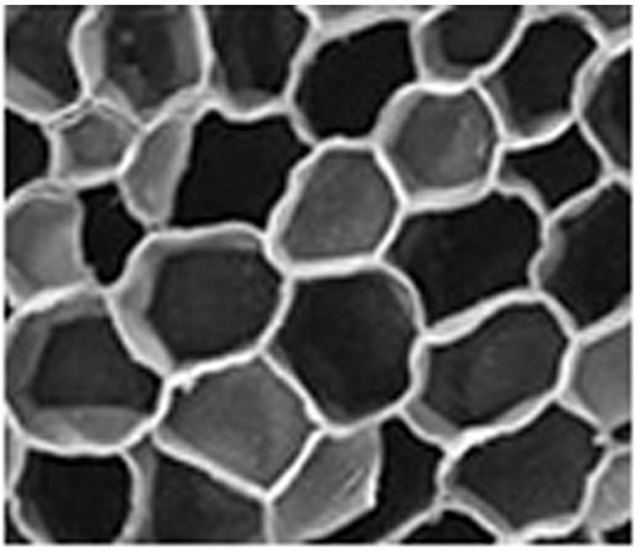

Figure 1. Cork radial section – cellular microstructure. (Silva et al.)

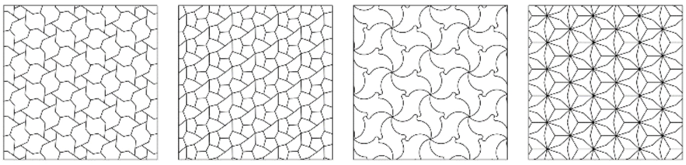

Figure 2. Parametric patterns based cork radial section.

3.1.2 *Cork samples*

Four patterns in five different types of cork products were prototyped. 500X500X20mm boards, ½ depth cut, Ø 3mm milling tool, were the common parameters to the five types of cork boards and to the four patterns (Figures 3-4).

In order to obtain some specific input to design of the main shading system some distortion and flexion testes were conduct in order to establish geometrical boundaries, assembly potential conditions and hypothetical board’s organization.

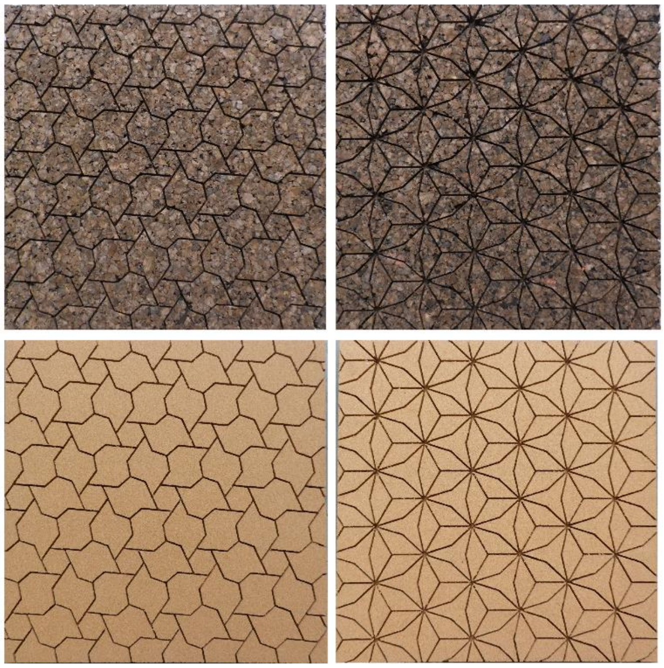

Figure 3. Two different patterns (Escher on the left and Earth on the right, two different types of agglomerated cork – expanded agglomerated cork (top samples), composite agglomerated cork (down samples).

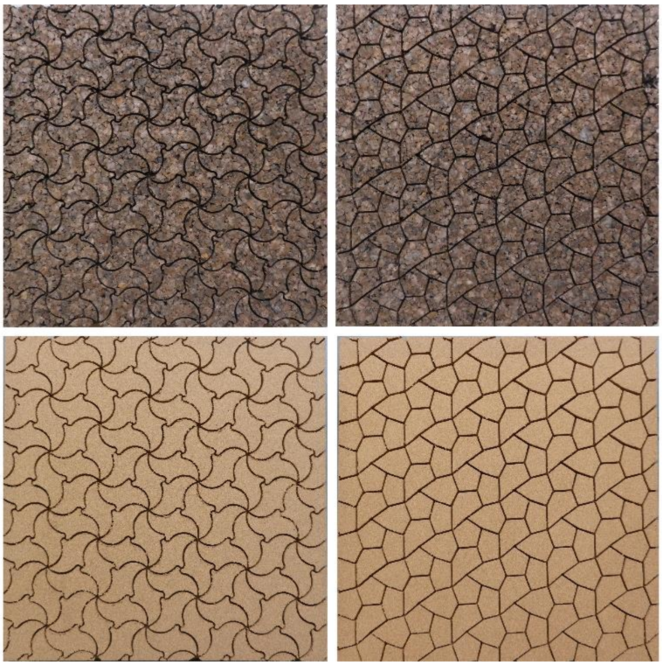

Figure 4. Two different patterns - Tile on the left and Islamic on the right - two different types of agglomerated cork – expanded agglomerated cork (top samples), composite agglomerated cork (down samples).

3.1.3 *Flexion*

The flexion test was conduct with the following tools: (1) Two idlers with predetermined diameter (related with the material thickness), working as two support points, apart with a pre-establish distance related with the length of the material sample; (2) A semi cylindrical axe.

The goal was to analyze the behavior of the sample, simulating a bi-supported beam by a bending test at three points (Figure 5).

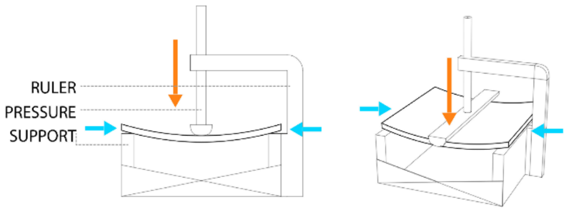

Figure 5. Flexion test representation.

3.1.4 *Distortion*

This test was conducted with the following tools: (1) Two idlers with predetermined diameter (related with the material thickness), working as two diagonal support points, apart with a pre-establish distance related with the diagonal length of the material sample; (2) A semi cylindrical sand container axe hung to the two free diagonal points.

The goal was to analyze extract values from the curvature behavior of the sample, simulating a bi-supported beam by a bi-bending test at two points (Figure 6).

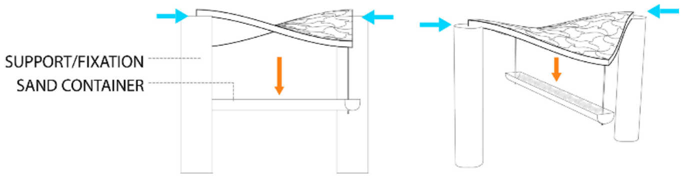

Figure 6. Distortion test representation.

3.2 *Stage 02: System – Form, Structure, Material*

With input from the material tests, parameters were generated and several boundaries and values were determined as design drivers. From the material tests two possibilities emerged as separated logics with the same fundaments: (a) explore the pattern potential as a self-material assembly, and work the boards as plan corps or (b) explore the pattern potential at two levels, at the bending board possibility and as self-assembly boards. At this point we know that the bending potential only could exist adding a malleable but resistant material, such as metal (Figure 7).

In both possible solutions, the assembly process only considers the material properties, its weight, friction, elasticity, flexibility, traction and resistance. The form of the system is intimately related with the chosen solution. On the one hand the system could work as diamond defined by its limits, uniform and consistent, reflecting a secure compromise between the different elements of the organism. Or, on the other hand, the system could be unbound at edges, working as a two face structure (two materials), self-supported and assembled, exposing its full strength as a material, as a structure and form – a full integrated system. This latter system is being simulated in a Rhino/GH (Grasshopper) workflow. Material properties and characteristics are being loaded through Geco and structure is being tested through Kangaroo and Karamba (GH plug-ins).

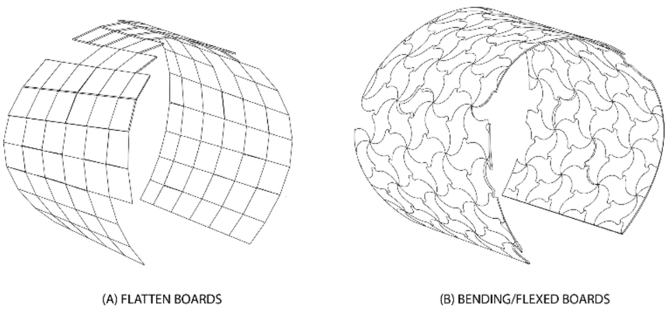

Figure 7. Shading system – structural essays and pattern application.

3.3 *Stage 03: Integration design/Environmental analysis*

Towards material tests and shading system structural simulation, environmental analysis is being integrated in the workflow. All the processes run simultaneously such that the results of one interaction, potentiate and improve aspects of the other interactions and forms. At this stage of the research, the work considers climatic analysis, based on weather file information using LadyBug (GH plug-in) for connections between the available data, geometry and materials. It integrates confort and measurable indicators such as *Thermal* (PET- Physiological Equivalent Temperature) and *Daylight* (adding Honeybee GH plug-in). The parameters are: Thermal - influence the heat balance of the human body – temperature, shadow, radiation, air direction and velocity, etc. Daylight - illuminance and luminance values.

Geometric reconfigurations are being made so that the system is able to react to those climate conditions represented through thermal and daylight comfort. The parametrization of the process defines the dynamic movements of the elements. The predominance of and sustainability of the system will always reinforce the design driver criteria that mostly constrains its geometric parameters (Figure 8).

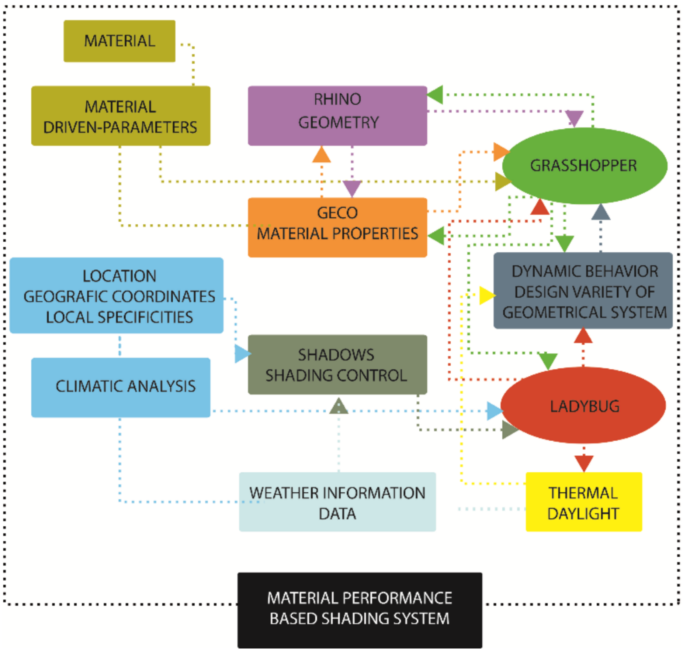

Figure 8. Diagram of the process, resources order and connections.

4 RESEARCH INSIGHTS

At this point, the research work is still open to the two possibilities announced in 3.2. However other factors have been added such as the importance of keeping the system restricted to one material, and therefore keeping the production capacity tie to one unique type of industry. This will avoid additional costs and enable a faster production and control of the entire process – from creation, fabrication, transportation to local assembly.

Another important conclusion has been extracted from the cork samples physical essays. The durability of the system could be an important factor for its commercialization and potential application. Being made (in its majority) by cork it's an assumed seasonal/temporary system. However the system should contemplate the possibility of being renewable or even prevent the possible substitution of parts during its life cycle time-lapse.

5 FUTURE WORK

Additional aspects of research and testing can bring further potential towards the development of this system. Other unmentioned material variables could determine decision making criteria for the proposed possibilities. Such variables as material thickness, density, the cut depth, the diameter of the milling tool, the section of the milling tool – these are all parameters that are determining to the form-finding process.

Other following steps are related with a more exhaustive structure of the parametric definition. The connection between geometry, design driver, environmental data - through plugins – can find different methodological choices which are informed from a logic process that prioritize some parameters and solutions according to the initial inputs of the target environment and user.

Towards this objective, the development of this work includes the creation of a pattern for a specific physical location. Variables of a specific shading system will be created and a virtual essay will be prototyped to scale 1:1. The prototype will be tested in laboratorial conditions.

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