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This publication has its origin in the paper proceedings of the
that was held in Lisbon, from 11th to 13th July 2016.

Edited by Instituto Universitário de Lisboa (ISCTE-IUL)
Architecture InPlay Conferences 2016,
curated by Alexandra Paio,

Printed in Lisbon, Portugal, 2016

Paper ISBN: **978-989-732-804-6**
Digital ISBN: **978-989-732-805-3**

Passive Shading System

Towards Parametric Definition and Virtual Simulation

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Abstract: The following article aim to present results of a parametric study of a passive shading control system. The fundamental hypothesis supporting this system find its basis in the natural behaviour of the applied materials - Cork, as well as in its internal and external exchange of data and environmental inputs. Inspired by natural physical elements, the main target is to develop a parametric definition that is formally expressed and designed responding to determined environmental conditions, interacting with the temporary space and surrounding inhabitants.

***Keywords**: Shading system; Cork; Parametric; Performance; Passive systems.*

1. Introduction

Visiting the nineteen century, human constructions were composed by tick walls and small and 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 twenty century, floor/ceiling walls with narrow steel frames, and the mass production possibilities engage the eternal contract between humans and artificial air ventilation in the interior of the buildings and structures.

At this point architecture and design has been think and developed, by layers of complementary information. Fragmental pieces and different parts that sustain each other by addition such a succession of information data. Form, material and structure are expressed and worked as distinct components of the same body, working independently from each other. However in nature there is no such distinguish. There is no natural body or system, where structure is independent from material, or material working separately from form, or even form composed independent from structure. In nature, elements rise as homogeneous systems, with no distinguish between assemblies or parts. The same element is structure, form and material.

1.1 Related work

In the last decades several strategies and techniques were developed, tested and constructed to achieve passive control systems. Starting with mechanical resources, then introducing photovoltaic technology and more recently based on biological organisms.

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Probably, the first relevant example of shading control systems attached to building façades was the *Los Angeles County Hall of Records* (Figure 1 – Left) from 1962, designed by Richard Neutra and Robert Alexander. Designed to be energy efficient, the south façade of the building it's totally covered with aluminium louvers. Originally made to turn with the angle of the sun throughout the day to allow more indirect light into the building. The system became inoperable few years after its construction. The expensive maintenance and ageing of the components of the system, have knock it off the mechanism and now all the louvers are locked in one fixed position.

In 1987, Jean Nouvel start constructing the *Institute de Monde Arabe* in Paris ((Figure 1 – Right). Referring the south façade of the building, Sharp (1990) describe the composition of the façade as an ocular device composed by numerus and variously dimensioned metallic diaphragms that operate like camera lens controlling the sun penetration into the interior of the building. The mechanical sub-systems, are driven by photovoltaic cells instructors reacting by sun exposure, instructing the independent cells to shut during the sun day and to open after the sunset. This system is still functional, but the costs of its maintenance are still pointed as a trouble issue. Another important reference to this system are the short and narrow openings, only excused for the charismatic character that classifies the iconic building.

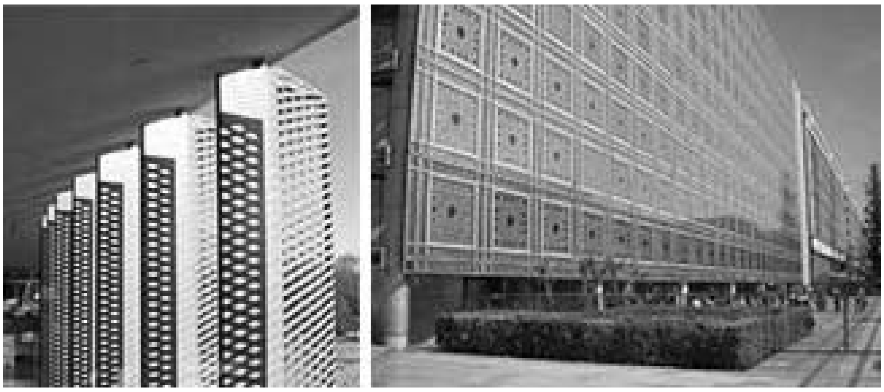

Figure 1. Left: Los Angeles County Hall of Records, Los Angeles, 1962; Right: e Institute de Munde Arabe, Paris, 1987.

During the last decade, new strategies for design, new materials and technics have emerged, based on biological models and processes by which natural material forms are produced. The self-organization of biological material systems are dynamic processes 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). The fundamental idea of the passive systems, are in this context, observed in natural forms and organisms and interpreted as a continuous feedback between structural forces and forms, raising at this point pertinent questions and potentials to rethink architectural systems, processes and bodies.

Bloom (Figure 2 – Left), designed by the Dosu Studio in 2012, it's a passive shading system projected to response to a particular and characterize site, based on the performative behaviour of the materials. Bloom is a bimetal structure installation that reacts to heat, generating increasing or decreasing openings in a pattern, enabling the shading system to adapt to its environment. The system key generator factor, was the profound knowledge of the material, its behaviour conditions, properties and characteristics, enabling a clearly development of the system behaviour and performance.

Other iconic experience is the ‘Hygroskin - The Hygroscopic Envelop Prototype’ (Figure 2 – Right) mobile pavilion based Achim Mengues, Oliver Krieg and Steffen Reichert. This building envelope makes use of the hygroscopic qualities of the wood (combined with fibres) to create a self-adjusted structure producing an open and close status, based on the relative humidity, silently and without electricity regulating light and air in its interior. More than finding architectural surfaces as solutions, Menges research group “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).

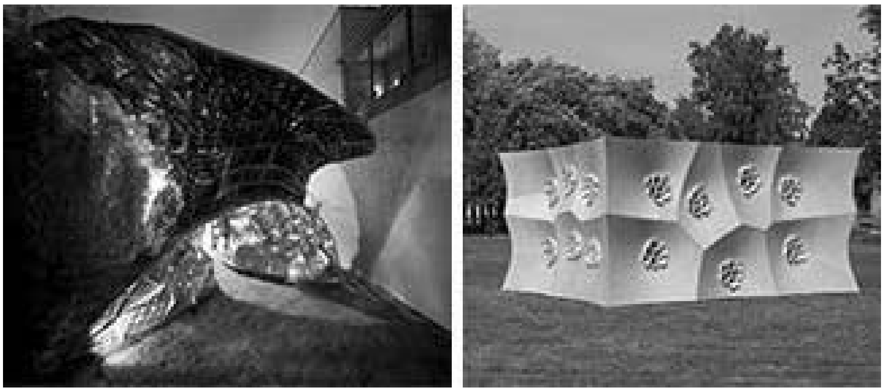

Figure 2. Left: Bloom, Los Angeles, 2012; Right: Hygroskin - The Hygroscopic Envelop Prototype, Stadtgarten Stuttgart / FRAC Centre Orléans, 2013.

2. Objectives

2.1 Scope

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

2.2 Goal

The main goal defined for this stage of investigation, was to explore through parametric design tools the potential, limits and boundaries of the cork material facing flexion and distortion. The final goal was to determine the bending and distortion material capacities, its limits and physical boundaries to inform the main parametric definition of the shading control system.

3. Hypothesis

The fundamental hypothesis supporting this investigation project is based on the cork microstructure geometry and its physical constitution. The idea is, based on the radial section of the cork – its geometric stylization and exploration, generate several geometric patterns, that when printed on the cork boards, will enable the boards to bend and distort in a range of limits that will determine and inform de final form and structure of the shading system. The relevance of this step of the investigation will also determine the geometry type of the assembly of the system.

4. Methodology

4.1 Cork Microstructure

At this stage it's for us fundamental to study and understand the physical (formal and chemical) structure and composition of cork. Material properties are intimately related with material performance. Categorized as an anisotropic material, cork as three different sections, (a) two of them are structurally similar, tangential and transversal sections, are composed by a 'brick' wall composition organized in a 1/3 proportion; (b) and the radial section also called as the honeycomb section, composed by a hexagonal geometry. This physical/geometric organization of the cork microstructure inputs the flexibility and elasticity for what cork is well known. The chemical condition of cork is mainly composed with 15% of cell walls - composed by suberin, lignin and cellulose, and with 85% of pure gas. This chemical constitution of cork is the responsible for its material resistance and resilience, when facing compression and distortion.

Being known for its undoubtable acoustic and thermal competence and efficiency, cork it's currently applied, mostly in hard construction as a thermal insulation or as a vibration floor. But in the last decades, with the improvement of offer of new cork products, the industry are focuses in the development of new types of products and studies of new potential forms and applications.

4.2 Cork driven-parameter

At this stage of the investigation two types of cork products were considered. EAC - Expanded Agglomerated Cork (also known as Expanded Black Cork) and the CAC - Composite Agglomerated Cork (also nominated as Composite Cork). EAC it's a 100% natural cork product, produced after high temperature compression of the grains, that enables the expansion of them, releasing the lignin and suberin that enable the aggregation of the grains. Its coloration, driven from the high temperatures process, its black. CAC it's mostly composed with resins. The aggregation of the grains its made by artificial products, auditioned to the heat compression process. More heavy and, in general, with higher density compared with the EAC, its coloration conserved the natural coloration of the cork raw material.

The initial tests had considered the original radial section of the cork, correlating its physical geometry with its structural integrity. So the geometric exploration/parametrization were based on the mathematic expression of relation between cells walls thickness, its gas volume proportion and material thickness expression. Manipulating these geometry driven-parameters four different patterns have emerged (Figure 3).

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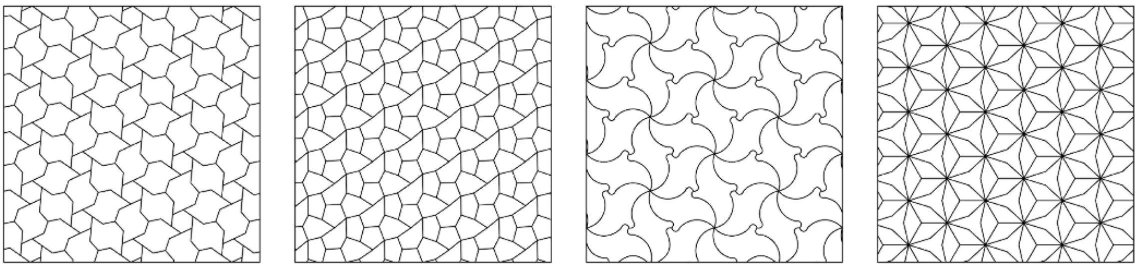

Figure 3. Pattern designation from left to right – Escher; Islamic; Tile and Earth.

4.3 Digital > Physical > Digital

In order to improve the parametric definition and enrich the form/structure relationship, physical tests were prototyped. Through computer numerical control (CNC), several prototypes were produced (Figure 4). The four patterns were printed in the two types of cork (EAC and CAC), with similar dimensions – 500X500X20mm - using the same depth cut (1/2) and with the same diameter tool (3mm).

The idea was to compare the behavioural performance of the material when worked with each of the patterns. The intended parameters to extract were the limits of bending and distortion of each board (each pattern applied to each type of cork and densities). These are valuable parameters to input not only in the assembly composition, but also to inform the global form of the system, working the limits of its components.

Physical tests were conducted. The boards were exposed to distortion and flexion tests enabling us to extract numerical values to input the boundaries parameters – each type of cork has its limits range of values.

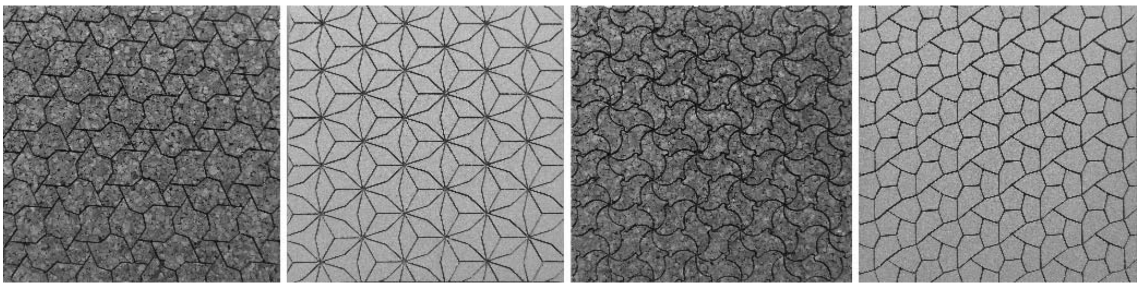

Figure 4. Prototyped patterns, from left to right – Escher; Earth; Tile and Islamic.

4. From material driven-parameters to form driven-performance

The first digital essays of the system, after the material driven-parameters inputs points up two totally different formal approaches.

The first possible conception of the passive shading system form, works with a modular composition of plan boards, exploring the potential of the modular form in its own body and flexion in its modular assembly capacity. This type of system aim to be reconfigurable in its own physical form condition, being also self-supported, and adaptable not only in its digital form but more important in its physical condition. The second possibility it's to explore the flexion and bending capacities of the material, working its self-support condition based limits of tension. However, this solution closes the capacity of physical adaptation and flexibility of the system in the digital process, being the form totally closed after the assembly process. Being totally conceived in digital environment each produced system will be always new, for each environment, for each inhabitant, for each individual context.

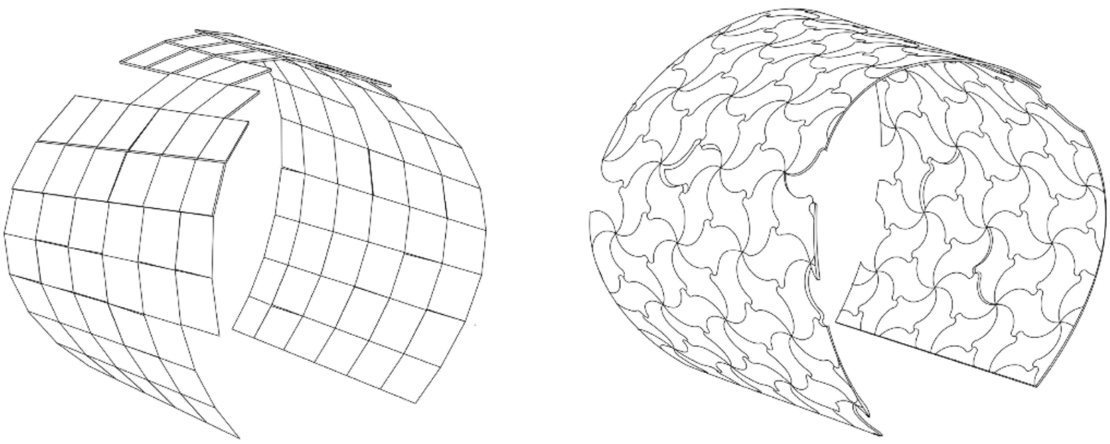

Figure 5. Initial digital prototypes of the shading control system – exploring boards application.

5. Insights and future work

Important conclusions have been extracted from the cork samples virtual and 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.

Following steps are related with a more exhaustive form finding structure of the parametric definition. The connection between geometries, design driver, environmental data - through plugins – can still find different methodological choices which are informed by 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. Environmental conditions such physical surrounding constrains, inhabitants usage and even shading system typology – shell, façade, temporary installation - will always be some of the most determinant driven-parameters of shading control system conception.

Acknowledgements

The authors would like to thanks to the Amorim Group. A special thanks to Dr. Carlos Manuel, Engº Lopes Infante, and Dr. José Andrade from the Amorim Insulation Industries and to Dr. Marina Rodrigues from the Amorim Cork Composites Industries.

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