

Form finding process for bamboo structures

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Abstract

This article aims to disclose the developments of the research on constructive methods of lightweight structures - made of bamboo in its standard forms, as nature gives us - developed by the Laboratory for Investigation on Living Design, LILD, from the Pontifical Catholic University of Rio de Janeiro, PUC-Rio. One of the objectives of this paper is to show how we can systematize constructive processes by means of experiments interactions in order to understand how nature creates its forms. In the Laboratory, experiments with soap bubbles, catenary curves, and other natural formations, have been serving this purpose, interacting with the researchers experiments in all of its different states.

Keywords: design, architecture, bamboo, biomimesis, covering structures, lightweight structures

Introduction

When it comes to placing shapes in the physical environment, the actor can be moved by two aims: the first one is conceiving shapes in their own psychological reality, the second one is disclosing shapes outside of his/her mind. The first intention is, usually, the one used by the majority of professionals in fields such as architecture, design and other related ones. On the one hand, this exercise of devising shapes, in the majority of cases, incited and demanded since the beginning of the professional and academic lives, is considered the primary way of innovation and creativity in this area of study. On the other, we ask ourselves how innovative and efficient these new ways of predetermined authorship are, when compared to the formal/functional infinite presented by Nature.

The second, therefore, is unveiling shapes from the lesson Nature gives us when we observe the dynamics of its formations.

1. The importance of the Reflection

It is clear we cannot deny the human creative capacity. Throughout our existence, our species has been modifying the world around us to better adapt to the hostile environment we live in. By means of instrumentation and projection, men were capable of occupying and exploring almost the entire Earth surface, dominating and surpassing a great diversity of natural obstacles.

However, the technological instrumentalist practice left aside another important factor of the human mind: the reflection. The instrumental world, as pointed by Illich (1976), and later by Flusser (2011), belittled this human ability, becoming the great truth of the modern world. In this sense, the instrument has ceased to serve men, so men serve the instrument.

Education and research, as shown by Freire (2011) and Illich (1976), became tools of this instrumentalist expansion, shaping new generations according to the demands of this practice, limiting greatly the real human creativity, a result of their reflection about the world. Thus, this practice cannot be called knowledge “because students are not required to knowing, but to memorizing the contents narrated by

the educator” (FREIRE, 2011, p. 96) instead of doubting it, which would incite questioning, dialogue and reflection.

Even when individuals possess “accumulated knowledge”, their personal experience will be stuck in this instrumentalist conception of the world. Therefore, their practices take advantage of only a fraction of the existing possibilities in the universe, a short existence stiffened by instrumentalist paradigms. We start to understand that the authorship conception of shapes, ins spite of, supposedly, working with concrete concepts of the future object, it translates all of its efforts merely into a system of representation of the author’s psychological reality, a system of representation that, according to Harvey (1993), “is a kind of spatialization that freezes automatically the flow of experiences and, in doing so, destroys what it strives to represent” (p.191). Thus, these representations are no longer a window into the world, but become a *tromp-l’oeil*, that is, a simulation, and, then, the agent, instead of being served by shapes of its own psychological reality, authorship shapes, lives according to it. As stated by Otto (1979), the instrumentalist society wants to maintain what exists and think it can do so by freezing it, but, in reality, it is killing itself.

Meanwhile, nature possesses an informational *continuum* of millions of years, results of an infinite number of processes, adaptations and evolutions to be unveiled.

Hence, along with the researcher, or in default of it, Nature produces its shapes. What men try to do is to fit these formations into parameters, in order to reproduce them, which is limited by their technical capabilities. Nevertheless, after meeting, even if partially, some of these parameters, humankind turned to them as irrefutable truths, putting aside all of the other possibilities. When we stiffen the technique, we limit the possibilities working together with Nature.

2. Objective

In contrast with this point of view, we propose a brief look into the process of obtaining shapes for bamboo structures employed in the Laboratory for Investigation in Living Design (LILD) from the Pontifical Catholic University of Rio de Janeiro. There, we seek to accomplish structures at a low energetic cost, which are cheap and popular, making use of bamboo culms as they are presented in Nature: light weighted and resistant, as we know, among other properties disclosed in the course of the research.

3. Methods

According to Santos (2009), the system of objects and the system of actions build the geographical space, that is, the man's space. These systems work inseparably, so it is indispensable, for the object to exist, the existence of an action, and vice versa: "Space consists of an indivisible set, solidary and also contradictory, of systems of objects and systems of actions, not considered individually, but as a whole canvas where history happens." (p.63). Nevertheless, the action to which the object will be subjected – as well projected and imbued with meanings it can be – is individual, i. e., each being has its own interpretation, which comes from its realities – social, cultural, environmental, etc – about the object and its use.

Hence, we can state, as shown by Ripper and Moreira (2004), that "artificial shapes can be seen as representations of ideas. Many shapes, when achieved, can correspond to a determined idea." (p.7). At LILD, we make numerous models into different shapes and times, and, sometimes, these concrete forms are kept dormant, waiting for the moment to be reanalysed, because in each review, the object is seen in a different manner.

In order to complete the definition of space by Santos, we present Doreen Massey (2009), who states that space is a result of interactions. Each individual, like each object, has its own pathway and relations. These particularities are not overlapped, but, coexist, and by means of interactions, they design space. Each new interaction leads us to a different view of the object, so we learn more about it, simplifying the understanding of its configurations.

As explained by Ripper and Moreira (2004), the complexity emanated by the object itself is felt; however, it turns to be simpler in shape. Thus, "if the complexity is not in the shape of an object, it will be in the process of its development. This is because solutions emerge from a net interwoven in time and space, made of information, experiments and ideas" (p.7), or, in sum, interactions, as pointed by Massey (2009). In this net of meanings confectioned by means of interactions, to which objects and researchers must respond to, lies the complexity of the building of space. In this manner, we understand that:

There must be, however, facing the object in constitution, an awaiting time. A passive wait, mental, in which our perception is allowed to adapt to the new that concretizes an intentional net. This own net is fed by what was concretized and there is a diversion

towards the objectives established *a priori*; and a dynamic wait, in which the object is handled, free from the same intentional links, for this to be also presented in this dimension, independently from the commitments of these previously established aims. (RIPPER & MOREIRA, 2004, p. 7).

It is worth remembering that this interactive method of trial and error, employed at LILD to generate technical knowledge, the aim of researching, must be understood in its relation to assumptions and requisites according to the ones employed in the design project. The experiments are conducted by these previous ones. Hence, they are motivated, precede and result from the researchers' thoughts which aim to produce knowledge. In contrast, what we call spontaneous experiments, made unintentionally, is not a part of these assumptions. This is a mode of experimentation that is not based on anticipations, and can be usually noted in music and fine arts. The work in progress, in this case, is done and redone in the object under construction. This kind of experiment is also implemented at LILD, but these spontaneous experiments, which come directly from the subjectivity of the members of the laboratory, are not, in LILD's case, the rule.

3.1 States of LILD's research

In analysing ideas, mechanical concretisations - such as miniatures and objects in use – and electronic concretisations, applied in the development of research, we realize that all this is interconnected, and, obviously, refers to the object studied. Considering this object as a model, we can notice that the research can be understood from a prism of states this model possesses.

Every state allows the analysis of the object investigated according to different, particular views, connected to the characteristics each of these states have. There is, however, a state to which all others are subordinated, the mental state.

The initial idea is in the mental state, which is the root of the development, that is, the starting point of the research. This state, initially, is formed of the understanding, *a priori*, of the researcher on the subject / research to be developed, and is enriched, and even changed, by responses obtained with the development of the other states, which, at LILD, are three (CORREIA DE MELO, 2011) (Figure 1): the mechanical state, the “in use” state and the electronic state.

The mechanical state (Figure 2) refers to the concretized models. These are miniaturized models, parts of the object in real scale, *mock-ups* and models for the study of technologies to be used. This state is the

most employed at LILD to study and to enrich the research. Before being a representation of the mental state, the mechanical one is, above all, a concrete object, and because of that, is subjected to some physical elements that act in the world, such as gravity, luminosity, weather, the action of time, among others.

The tactile experience in handling the model allows the observation of new angles, the incident light, the sensation of fullness and emptiness, and textures. The direct manipulation of the materials to be employed enhances the relationship of it with the researcher, bringing more intimacy and expertise to the conduction of the technique. In addition, the model in the mechanical state, when experienced, involves not only the touch, but also the sense of smell and other senses. With the increase of information channels in the active exploration of an object, the experience is improved by the increasing of the flow of sensory impressions. Being familiar, for example, with the smell of the materials utilized enriches the research, and this experience is crucial to a better understanding of shapes and mastery of their potential.

The state in use is the object in real scale and ready to be utilized. This is also a mechanical object, however, it does not fit the previous definition, because it is a resolution of the knot of tendencies present in the mental state, as shown by Levy (2001), but more accurate. That is exactly why this state happens usually after the others. In most cases, it is as a result of the answers obtained from the other states. Additionally, it also brings new data to the research and, clearly, to the mental model. In this state, it is relevant and practical to use the technique and materials with high precision, resulting in productive models of sources of information. That is, all exchanges of information are in evidence.

The electronic state, unlike other ones, is beyond the mechanical world, then, alien to forces that act in this world. Basic concepts such as gravity and temperature can easily be distorted or denied. The natural laws that would apply the model if it existed in the real world do not exist. Instead, the electronic object reacts only to the laws written by the software programmer. The relationship of the electronic object with the user will always be via a two-dimensional channel, i. e., a computer screen. In addition, this alienation, allows new insights about the object in study, enriching the research.

3.2 Interactions between the states of the research

The states alone do not conduct the investigation. It is in the interaction between them that the research works. The states serve as stations of understanding about a certain topic studied. They are elements of resolution of virtuality, according to the concept of knot of tendencies proposed by Levy (2001),

pertained to the study. These states are like a summary of what was apprehended until the time of its confection. They serve as a new starting point for both the study and the resolution of new issues, as well as to clarify and approach further to the resolution of previous unresolved issues.

In this manner, we believe that the data inserted in the confection of different states, whatever it is, is what moves and drives the research in progress. Furthermore, the states are crucial in obtaining such data. Thus, we conclude that the states are fed back, allowing the continuity of the studies. We understand, then, that the ones responsible for conducting the research are the interactions (Figure 1) between the states, not each of them working alone.

These interactions occur in many different ways; there is no particular order or direction. It is true that a greater number of interactions will result in a greater number of issues resolved, and, consequently, more solutions will be found. However, as it happens in the states, there is a first interaction, which will always be recurrent and will be put above the rest: it is the interaction between the mental state, and the others individually.

This first interaction is constant, intense and continuous. We can consider it as a reflection inherent to the act of making something. Whenever we are doing something - models in mechanical, in use, and in electronic states - we reflect on our work, creating a dialogue between our mind and what we are doing. This dialogue is what conducts both the development of the study and the necessary steps to overcome the resolution stages of the knot of tendencies and possibilities, leading to completion, at least temporarily, of what is being confectioned.

However, interactions between the mental state and the other ones individually are unable to conduct the research alone. As mentioned, each state responds to a certain type of characteristic necessary to the resolution of the problems faced when developing the research. If we explore only the first type of interaction, we will move very slowly, being almost stagnant, since we will be held in characteristics inherent to an individual state.

Therefore, it is noticed that all of other interactions, along with the root one, will generate data to enrich and develop the research at LILD. The interactions are as follows: 1) mechanical state x state of use; 2) mechanical state x electronic state, 3) electronic state x state in use, and 4) interaction between all states.

4. Form finding process

In order to better explain the process employed at LILD, we present the way by which, from the observation of an emblematic shape provided by Nature - the spherical surface - and the triggering of a set of elements and unfoldments of such shape, we descry a series of understandings capable of generating functional objects. They are still being tested, processed and transformed, and, hence, are not limited, always pointing to new starting points.

Our planet has a roughly spherical surface. Our body is formed in great part by cells whose shape is close to the one of the sphere. The surface of a grain of sand also tends to this form, as well as many other elements in Nature. This has encouraged us, from the laboratory, to direct our attention to the sphere (Figure 2).

We have started the studies of this surface in light of Richard Buckminster Fuller, the father of geodesic domes. We have concretized a number of geodesics, which are lattice domical structures, whose polyhedral faces describe the spherical surface. During these accomplishments, we realized that the problem of a cheap and accessible to the public geodesic - our objective - were its bonds, which made the construction of its structure a very specialized one, failing to meet our goals. Fuller did not use bamboo in his domes, and the existing joints, made with and for other types of materials were inappropriate for the low tangential resistance of the culm. A number of joint types suitable for bamboo were, then, studied. Solutions that dealt with punctual joints and *tensegrity* structures have shown to be proper (Figure 4 and Figure 5).

The *tensegrity* structure, by connecting every two of the geodesic's elements instead of all of them in a converging point - as it is usually done around the world – has shown to be more appropriate. We have observed, during the construction of the *tensegrity* structures, that the bond area of its five and six bars joints which is correspondent to the vertices of the polyhedron is very simple. These bars were tied every two, creating a spin and an empty space around that mathematical vertex (RIPPER, et. al., 1995). We call this structural node “spin”, which works mechanically similarly to the reciprocal beams structures (Figure 6) (PIZZIGONI, 2008). This disclosing, by simplifying the construction of bamboo geodesic domes – a material easily accessible to the population – has made this structure popular in Brazil. Its

dissemination has reached a variety of sectors in society such as education, construction, scenography and theatre (Figures 7, 8, 9 and 10).

We have carried on the study of spherical surfaces and started to examine inflated surfaces made by nature. To study this, we read some of the works of Frei Otto (1967), who applies the deformation parameter of soap bubbles to the development of lightweight structures. This study can be done by artisans, and in the present time, through specific softwares. Soap bubbles follow the same formation principles of inflatables found in nature. They are made primarily of a mixture of soap and water, which, once inflated, form very fine surfaces – 1/1000 millimetre thick. The surfaces formed are spherical when released in the air. When laying on surfaces, bubbles tend to assume the shape of spherical caps. This surface formed is always a minimum area – the one with the lowest energy cost possible.

We have performed some artisanal studies with soap bubbles, which assumed a variety of shapes controlled by the researchers. According to the parameters given by them, the bubbles always responded with minimal surfaces (Figures 11 and 12).

However, a characteristic of soap membranes is volatility, which makes difficult to work with them for a long time, as well as to measure accurately their surfaces. To overcome this obstacle, in parallel with soap membranes experiments, we have also tried inflated latex membranes and funicular (catenary) models, allowing us to freeze the shape through the employment of concave moulds (Figures 13 and 14).

These moulds were the basis for the triangulation of small bamboo bars. Such action follows defined geometrical parameters, in order to reduce the amount of different-sized bars, which lead us back to Fuller's geodesic process. At a first moment, a reticular geometry with punctual joints was obtained, and later - following what had been learned from the tied up bamboo dome - we applied the "spin" joint. These experiments resulted, until now, in two "in use state" models, the second one being quite significant: the first is the Yvy Porã dome, the cover of an experimental workshop in Florianopolis-SC (CAMPOS & MELO, 2010, 2011); and the second one is the cover of the LILD's new building, which was assembled and is in use by LILD's team at the moment (RIPPER et. al., 2011)(Figure 15, 16, 17, 18, 19 and 20).

In late 2011, the University asked us for a classroom without foundation - because the whole area as possible to conventional constructions, by law, had been used – and so, they indicated to us an area of 6.00 m by 7.70 m, in the parking lot. This way, we returned to the study of deformation of soap bubbles, however, by replacing the former square base to a rectangular base. At this point, after a series of models

in all states (Figure 21, 22, 23 and 24), we are in the process of realization of the object in a state of use (Figure 25). We call it “The Bubble Hall”.

5. Final Considerations

This is only an example of some of the possible developments of observations on shapes made by Nature which, without a doubt, have not been exhausted, and probably will never be. It is worth remembering that this process is not linear and is not the only study performed in the laboratory, and because of this it is under the – intentional - influence of the other ones.

The method employed at LILD is the trial and error one, which can be observed on the research of techniques – the “how to do” -, and on the process of designing objects - including architectural structures. The subjects covered in this paper represent a small portion of the body of work that has been done, without interruption, since the opening of this laboratory.

The development of techniques on bamboo structures led us to study raw clay for its enclosures. Nowadays, we combine both materials, when possible, on the same object.

The bamboo structures, when covered by raw clay, put fungi and insects away - which lives in profusion in the hot and humid regions of Brazil. This statement is proven in architectural buildings of our colonial heritage - some of which are still in good condition.

About the work teams, they are integrated of intern students and post-graduation researchers .What we expect from this team is a collaborative work, without restrictions of area of expertise or hierarchies. The subjectivity of each member must emerge and manifest itself, but the authorship should be dissolved into conversations and I into lessons given by nature when touched by our experiments.

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7. Figures Captions

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Figure 2 – Human body fat cells

Figure 3 - Sand grain

Figure 4 – Geodesic dome made of bamboo. Punctual joints

Figure 5 – Tensegrity geodesic dome made of bamboo

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Figure 7 – Passing on bamboo geodesic dome technics

Figure 8 – Bamboo dome assembled for an exhibition

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Figure 10 – Bamboo dome as a structural core for the construction of a chapel in Andrelândia.

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Figure 15 – Obtaining the bamboo lattice with “spin” joints

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Figure 17 – Yvy Porã dome (square-based bamboo dome)

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Figure 21 – Rectangular base soap bubble

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Figure 23 – Soap bubble in mechanical state – paper model

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