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Learning from Bamboo: Building a Bamboo Structure Collectively

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Abstract. *In this article, we explain the experience of building a bamboo garden house out of Bambusa oldhamii in Central Florida. We define the bamboo's characteristics – a strong, fast-growing and lightweight material and the best way to harvest it. And we explain the design process of the structure, that is freestanding and the connections are done with lashing. The learning and building process is described and we understand this experience as an opportunity to learn how to think in a systemic way, having Buckminster Fuller as a reference. The choice of using a local and renewable material and building in a collective way are all part of the design.*

Keywords. *Bamboo Design; Collective Design; Local Materials; Freestanding Structure; Lashing; Lightweight.*

1 Introduction

This article explains the experience of creating a bamboo structure - our aim in this project was to use the natural characteristics of bamboo, working with simple tools and making a structure that would be self-standing and stable. We also intended to build a structure that would last as long as possible without using any chemical treatment. In order to describe the process, this paper has an interdisciplinary approach – as it is the collective work of a horticulturist, a designer and an educator, it approaches aspects of harvesting bamboo, designing with bamboo and learning with bamboo. Thus, we start by explaining about bamboo's characteristics and harvesting process and then we explain the design process and the workshop.

Bamboo has been used a lot by designers and architects in recent years – the use of bamboo laminates and other processed forms of bamboo has grown a lot. But in this paper, we explain the use of bamboo in the most raw form as possible – not going through any industrial or chemical process.

The use of raw bamboo has been studied by LILD Lab (Laboratório de Investigação em Livre Desenho), at PUC-Rio University, in Rio de Janeiro – the research done by this lab is the basis of the design process we have worked with. For over 20 years, this Lab has been doing research on lightweight structures with natural materials - bamboo, natural fibers, clay, natural resins. The bamboo structures that the lab works with are done with lashing, avoiding drilling holes in the bamboo and using screws, so that the bamboo's structure isn't compromised.

The use of these materials and structures is often taught to people by the Lab in a participatory design experience. Sharing the knowledge and building together is an important part of the process. The use of bamboo and the knowledge to work with it can teach a lot about material structures and processes – from harvesting the material to its final use.

Bamboo is known to be at the same time strong and lightweight and it is a good tool to learn in an active and collective way. With bamboo, we can also learn a lot about lashing and the creation of stable structures. We can observe that structures done with lashing can create a system, in which each part is essential to stabilize the unity.

In the project that we will describe, the aim was to use the bamboo that was locally available, that had been planted and harvested on the property by one of the authors – she has been planting and managing bamboo for some years in Orlando, having gained experience with bamboo. We also chose to reuse the tin roof that was also available on the site, in order to avoid acquiring new materials.

Our aim in this article is to defend that bamboo can be a tool to learn about viewing whole systems and a means to view entire material processes – from harvesting the material to creating an object with a biodegradable material. Thus, creating with bamboo collectively can be a way of learning and designing in a more comprehensive way.

In this article, we start by explaining some of bamboo's basic characteristics – knowledge that we were based on as we developed the project.

2 Bamboo's characteristics, harvesting and treatment

Bamboo can be found in the Americas, Africa, Asia and the Pacific. It grows mostly in warm climates, in the tropics and subtropics, but can also be found in very cold climates, such as northern China. (Rockwood, 2014, p. 12)

There are over 1500 variations of bamboo, with different sizes and characteristics – the main distinction in bamboo species is between running types of bamboo and clumping types of bamboo.

In this project we worked with *Bambusa oldhamii*, a species native to Taiwan. It is a clumping bamboo, with green culms reaching a maximum of 10 cm (4 in) in diameter. In the United States, it is also known as giant timber bamboo. It is the preferred choice for building in the Southeastern US, as it is stronger than the other species that grow there. *Bambusa vulgaris*, the most common species in the US, is not a good choice for building because of high sugar content that attracts insects.

In the Americas, the use of bamboo is very old. According to Oscar Hidalgo Lopez, in pre-Columbian America, there used to be a great bamboo tradition.

At the arrival of Columbus, there was a bamboo culture in the Americas similar to that of Asia, and the two most outstanding bamboo culture centers were located in Guatemala, Central America, and in the area of Colombia and Ecuador. According to Resinos (1952), the city of Guamarcaah, was the largest and most important city of Central America (...) This city was called by the Aztecs of Mexico, Utatlan, that means “city of cañaverales”, because it was surrounded by bamboo forests. (Lopez, 2003, p. 367)

Nowadays, the biggest bamboo tradition in the Americas is in Colombia, where there are many popular bamboo houses built by the people, as well as many renowned architects that have been working with bamboo in a very sophisticated way.

Bamboo has a great variety of uses – especially in Asia, where it has the strongest tradition. But what makes bamboo most remarkable is the fact that it is at the same time resistant, fast-growing and flexible. And it is also known for being lightweight - a pole can be carried by a person alone.

The fact that bamboo is such a fast-growing plant makes it a sustainable material to use, since it is always regrowing. As Lopez explains,

Some giant culms of the genus *Phyllostachis pubescens* grow up to 1,22 meters in 24 hours. In less than five months, the culms of giant species like *Guadua angustifolia* complete their whole growth of 20 meters which, in many trees of the same diameter, takes many years. (Lopez, 2003, p. III)

Bamboo is also a very strong and resistant material, and is commonly known as the ‘vegetable steel’ – “The tensile strength of the fibers of a vascular bundle could be up to 12.000 kg per square centimeter, almost twice that of steel.” (Lopez, 2003, p. III)

Besides being a very strong material, bamboo also has a very high rate of carbon sequestration, as DeBoer & Groth explain: “It is stronger than any other common building material when used in pure tension or compression and more sustainable due to its speed of growth and rate of carbon sequestration.” (DeBoer, & Groth, 2010, p.3)

Although bamboo is a very resistant material, at the same time it is prone to the attack of insects and fungi that deteriorate the material. In order to make bamboo more resistant, there are many recommendations as to how to proceed, starting from the best way to cut the bamboo.

One must cut the bamboo at the optimal moment, so that it will last longer. Lopez (1981) says that the best time to harvest bamboo for construction is when it's from 3 – 6 years old – that's when the bamboo culms are mature and have reached their highest strength – later, its strength decreases. It is recommended to make the cut as evenly as possible, and the cut must be done above the first or the second joint above the soil. (López, 1981, p. 2)

It is believed that there is also an optimal phase of the moon and time of the day to cut the

bamboo, when there is less humidity in the plant.

Field observations have demonstrated that a correlation exists between the humidity content of the canes and the phases of the moon, and that there is also a correlation with humidity content of day and night. The humidity of the plant is lower in waning phases of the moon and in the early hours of the morning, before the sun rises. (Minke, 2012, p. 17)

After the bamboo has been cut, it is recommended to let it cure for a while in the bamboo bush: “Clump curing culms with branches uncut, leaving them to stand four to eight weeks propped in the grove controlled up to 90 percent infestation.” (Farrelly, 1996)

These are traditional instructions on how to cut the bamboo as to get the most of its strength and make it last longer.

After the bamboo has been cut, it is essential to treat it, so that it will be less vulnerable to the attack of insects and fungi:

The preservation of bamboo after the harvest is so important that it decides the quality of bamboo material in later utilizations. Similar to wood the bamboo is easily attacked by insects, fungi. According to Janssen (1988) the untreated bamboo culms can have a maximum of 10-15 years of lifetime if they are kept under cover and in a not very humid climate. In direct contact with atmosphere they can only last 1- 3 years. (Xiaobing Yu, 2007, p. 22)

Bamboo can be treated in chemical and non-chemical ways. Nowadays there are many chemical treatments, by bathing the bamboo in chemical solutions or injecting or spraying products on the bamboo. In this project, however, we avoided chemical products.

There are many traditional non-chemical methods, such as immersion in running water for a few days, so that the starch runs out.

But the most basic treatment is drying the bamboo. It is important to dry the bamboos before using them in construction or handicraft, for they become lighter and have less juice for insects. The bamboos can be dried in the shade by air, in a heater, by smoking the bamboo, or by fire, with a blowtorch. But one must take care so that the bamboo dries evenly and doesn't crack or deform.

Figure 1: Bamboo connection standing on a base

It is also very important to keep the bamboo protected - it must be protected from the sun and rain, so there must always be a good roof above it. And it must also be kept away from the soil's humidity – it must never be in direct contact with the soil. As the Colombian saying goes – “*Buenas botas y buen sombrero*” - “Good hat and good boots.”

3 Influences of Buckminster Fuller

The design of the structure that we will present here is influenced by the techniques developed by LILD Lab, that has a research on bamboo light structures.

The aim was to develop a freestanding structure – a structure that wouldn't need a foundation, and would stand on a base above the ground. Without having a foundation, the structure should create a stable unity. And the structure would be built with lashing and without drilling holes in the bamboo, as to not compromise the pole's structure.

The thoughts of the American designer Buckminster Fuller oriented much of what we thought about the design and the learning methods that come with it.

Buckminster Fuller studied lightweight structures, tensegrity structures and spherical geometry, and did research especially on geodesic domes.

Many of Buckminster Fuller's ideas are based on systems theory, understanding that the whole system creates a unity and has a behavior that is unpredictable by observing each part individually. Fuller believed that the Universe, in a wider view, cannot be predicted by observing each part by itself – we ought to give up observing individual parts alone and start by looking at the whole picture (Fuller, 1979).

Fuller created the term 'synergetics' – a contraction of the words synergy and energetics, synergy is a word used in chemistry and it occurs when the reaction between elements cannot be predicted by observing individual parts.

Synergy is the only word in our language that means behavior of whole systems unpredicted by the separately observed behaviors of any of the system's separate parts or any subassembly of the system's parts. There is nothing in the chemistry of a toenail that predicts the existence of a human being. (Fuller, 1985, p. 37)

With synergetics, the world is perceived as the interaction of energies.

Thus, Fuller believes it is important to have a great change in the way we think, having synergy in mind and always thinking about the relation between things – we should always have the 'whole' in mind.

Fuller also investigated tensegrity structures, which are structures that unite elements that are under tension with elements that are under compression, creating a stable unity:

He coined the term tensegrity by combining the words tension and integrity. Tensegrity structures exhibit an ideal balance of tension in which each element is perfectly aligned in the exact location where it is most “comfortable” while providing maximum strength to the overall framework. (Sieden, 1989, pg. 102)

4 Bamboo and Experiential knowledge

Designing, learning and building are experimental activities – one learns from trial and error. One can learn directly from the materials, especially bamboo, observing how different elements can

be connected and how they will interact to form something new. There are things one cannot imagine only mentally - one must learn directly from the materials and experiments.

As Buckminster Fuller teaches us, mistakes aren't something essentially bad – making mistakes is part of the learning process – by seeing a path doesn't work, one gains more knowledge (Fuller, 1979).

With bamboo, it is good to learn hands on – to learn by doing. Learning the gestures directly from one person to another, in a collective and practical way.

In order to learn about a large structure that will be built, it is good to start building the mini-model, in order to understand the structure – how the pieces connect together, creating a bigger unity.

Bamboo isn't a standardized material and each culm has its own subtle characteristics. Thus, it can't be thought in an abstract way – one must observe each bamboo pole and think how it can be best used, where it can fit the best.

Bamboo brings the possibility of having a building material that can be worked without a complex processing method. Structures that are done with lashing can be built with a saw and rope. Some other tools are welcome, but not essential. Therefore, bamboo enables gaining knowledge of the whole building process – from planting and cutting the material to treating it and building with it.

Besides, a visible bamboo structure is something from which people can always learn, even after it's ready. People can observe the bamboo connections and see the whole structure and with careful observation, one can understand how the structure works and how it might be done.

There are some examples of places around the world where bamboo is at the same time a building material and a tool for learning, like the “Escuela para la Vida”, in Cali, Colombia, a school completely made out of bamboo, with visible structures, where besides the school subjects, the students learn how to build with bamboo, in a practical way. And the whole experience of being in the school already teaches a lot about bamboo.

Figure 2: Bridge at the *Escuela para la Vida*

A good method for designing and learning about structures – is by using mini-models – when designing with bamboo, mini-models are especially helpful.

The miniature model brings the possibility to get to know the object in all its details and to see how its structure holds itself together. It is essential to the creative process, because one can observe how each element of the model works with the other elements, forming a unique unity.

The miniature model is much lighter than the full scale one, so there are some things it cannot show us. But it can show how each element will connect to each other and if it will be able to hold itself together and stand. As for the computer model – everything will stand, so it's not good for form finding in bamboo structures with lashing. The computer model will be useful to get precise measures once the model has been designed.

Building mini-models is a way of understanding how the different parts interact, and Buckminster Fuller believed it could lead to a better understanding of reality.

He felt that one of the best methods of understanding the physical and metaphysical phenomena which he felt dominated all Universe and the principles that control those phenomena was the construction and display of models. (Sieden, 1989, p. 26)

Bamboo is a good material to learn from miniatures, because with bamboo sticks, one can build the exact same structure that will be done in full scale, especially in structures done with lashing. It is easy then to understand how each element of the structure behaves.

5 The structure's design

The bamboo structure was designed to be freestanding and stable. The form finding method that was used was mainly building mini-models with bamboo sticks and lashing. Paper drawings and computer modeling were used to get more precise measures, but form finding was done with mini models.

A trellis was set diagonally on the roof to make the structure stable, so that the top square wouldn't deform.

As for the vertical poles, we used three poles on each corner in order to distribute the weight and to create stability – thus the structure can stand on its own, without needing foundation. This is good in a bamboo structure, so that it can stand away from the ground – as we explained, bamboo must be kept away from the soil's humidity. The structure has many triangles on its design, which is responsible for its stability – when all triangles are put together, it is unlikely that it will get shaky.

The structure was designed to have a 10'x10' roof. This measure was set with the intention of reusing a tin roof that was already available on the property – the idea was to use as much material available on the site as possible. As the legs are slightly tilted inwards, the floor would have a 7'x7' dimension.

Figures 3 and 4: Mini-model and computer model

The bamboo house was designed to be connected by lashing – other kind of connections would have led to different designs. There are basically two ways of connecting bamboos - with metal pieces and screws and with lashing, which is the most traditional way, but has been less explored nowadays. Modern architecture, as the one practiced in Colombia, uses metal pieces and screws, and drills holes in the bamboo. This works better on very strong bamboo species, such as the *Guadua Angustifolia* present in Colombia. If the bamboo is thinner, it is better not to make holes in it.

Traditionally, in indigenous cultures all bamboo structures were done with lashing, but this use became less common as more designs for metal pieces for connecting bamboos became available.

But with lashing alone, we can build structures that are very structurally stable and maintain the integrity of the bamboo. However, the structure must be designed to work well with lashing – the entire structure must create a unity.

LILD Lab in PUC-Rio University has been developing lashing solutions for bamboo for many years, making it possible to connect many bamboo poles together and creating stable structures.

6 Bamboo workshop in Orlando

The bamboo workshop to build the bamboo house happened in July 2018.

A few weeks before the building would start, the bamboo (*Bambusa oldhamii*) was cut and left to cure for some time.

The workshop for building the bamboo garden house happened on two Saturdays. On the first day, the participants got familiarized with the mini model, so that they could better understand the structure that was being built. Each person did a mini version of the roof trellis.

They also learned how to do the lashing. In this structure, we used two kinds of lashing – the clove hitch was the basic knot, used in all lashing points. To connect the legs, we needed a stronger lashing, so after the clove hitch, we put a tourniquet with a square knot. The tourniquet makes it possible to do a very tight lashing without the need of using too much strength – it enables people who are not very strong to do a very tight knot, and it enables people to do very tight knots without hurting their hands.

Learning the lashing is a very experiential process. It is something one doesn't understand in a theoretical way – one must observe the lashing being done and repeat it many times in order to get used to it. The lashing and building process is a lot based on trial and error - to get the tourniquet tight with the right length of rope, one must often do it and redo it many times.

Figures 5 and 6: Connecting the bamboo poles with square knots and using a tourniquet to tighten the knot.

A 1:5 scale mini-model was then built together, so that everybody could understand the whole structure and practice the lashing. In the mini-model, people can understand the lashing and understand how the structure works, and how it stands together.

Figures 7 and 8: Building a mini-model together to understand the structure and the lashing

Then, on the next week, we prepared to build the full-scale structure together. We measured and cut the bamboo pieces to length, and heat-treated the bamboo.

We built the foundation and the deck where the structure would stand, so that it would stay away from the ground.

Finally, we built the full-scale model together. We bonded together the legs and the roof square. We needed to observe the mini-model during the whole process – it is like a map of what's being done – which piece fits where. But the full-scale model is much heavier and therefore many hands were necessary to put everything together. Until all the bamboo pieces were in place, the structure was very unstable and it would fall apart if there weren't people holding it. But after all pieces were put in its place, it became very stable. This taught us in a very experiential way of the importance of each pole – the structure becomes a new unity when all the parts are put together.

We did the lashing for the roof trellis separately and it was placed on the top when the legs were already put together.

Figures 9 and 10: Building the full-scale model together

Figure 11: Building the roof trellis

The last part was to put the tin roof on top of the structure. The tin roof was screwed into some pieces of wood that were tied to the bamboo on the top – thus we would not drill holes in the bamboo. As was said, this roof was chosen because it was already available on the property and it was not being used – and it is very lightweight.

Figure 12: Final structure with tin roof

After all the lashing was done, the final structure was very stable, and participants were amazed that the bamboo poles that in the beginning of the building process were shaky, had become very firm in place.

7 Final Remarks

The structure we have built has taught us a lot about viewing the whole process – from cutting the bamboo to building the structure. We understand that bamboo is a good tool to learn geometry and structures that can be built with lashing in a practical and collective way. As we saw, bamboo is a fast-growing plant that is very resistant and it can be used in many different ways. In this structure everyone could understand that the bamboo poles could be connected, creating something new – a structure that became stable and freestanding and that depended on each one of the poles to hold itself together. The whole structure couldn't be predicted by each bamboo pole alone – it became a completely new unity.

In this structure, it was essential to have a group of people collaborating, because although each bamboo individually was lightweight, the whole structure was heavy and many hands were necessary to hold it together until all the lashing was done.

In this project, we tried to have a systemic approach, not viewing the object in a fragmented way, but as being made from many relations – the object itself is a system, a unit made from the integration of many parts. Each part of the object is essential for the structure. At the same time, the object is seen as being a piece of a bigger system, which involves the whole planet. Bamboo can be associated to systemic thinking of the object as it is a renewable material and it can be used in its raw form – without any industrial or chemical processing – unlike other materials such as petroleum and metals.

The systemic view of the object goes beyond its material characteristic, including a human aspect as well. People's actions give meaning to objects. Objects cannot be seen alone, but are always related to people's actions. Thus, it is important to observe how people affect objects and how they are affected by objects, and how this interaction influences the environment. As we explained, Buckminster Fuller shows we must always think in a non-fragmented way, observing all aspects – we must always think of the object with a systemic view, seeing all the interactions.

We believe this building process can bring the consciousness of this systemic view of the project - the bamboo house can be seen as a whole system in itself, and it can also be seen as a part of a bigger system.

This project also teaches about the importance of designing and learning by handling the materials directly. Drawing and computer modeling were used as an extra tool, to get precise measures, but they are not essential. The design process could not be done by drawings and computer modeling only – because these tools don't show us how the pieces work together, if the structure is stable and if it is freestanding. How the lashing will structure the design is also something that only a physical model can show.

As people were learning about the design and the structure, manipulating the rope and the bamboo was essential – it's not something one can learn theoretically. This is actually a limitation of this article – we cannot communicate about the structure's design by words and pictures only and it's limited to talk about this object without having the actual object before us to observe and touch. Other than that, as we were working with a raw material, that was planted locally, everybody could visualize the whole process – from harvesting the material to seeing the bamboo house. This

connects people with the material process in a very experiential way, giving them a full grasp of the object's life cycle.

From this experience, we believe that bamboo is a good material to learn about design and material processes in a comprehensive and systemic way.

As we explained, this was an interdisciplinary project, involving Horticulture, Design and Education – the knowledge of different areas was essential in order to create a whole view of the process. Having Buckminster Fuller as our main reference, we believe in the importance of having a comprehensive view, not fragmenting knowledge and understanding.

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