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The Potential of Bamboo as Building Material in Organic Shaped Buildings

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ABSTRACT
Bamboo has been widely known as a sustainable building material due to some reasons among others are bamboo can be easily cultivated and harvested in a relative short time and can be reused. Bamboo as building materials is easy to bend and lithe. Those characters are very suitable for organic shaped building construction. This paper attempts to discuss how bamboo is being used in organic shaped building. Several case studies are taken to describe the relation between shape, structure, construction and joint system. It will classify how bamboo is formed in curved thus result is an organic form. The paper result will show that bamboocan be a potential building material for organic shaped buildings and become an alternative building material other than steel and concrete.
Keywords: Peer-review under responsibility of IEREK, International experts for Research Enrichment and Knowledge Exchange.

1. INTRODUCTION

The use of bamboo as building materials has occurred in a long period. Most of traditional houses in Indonesia and Asia use bamboo as building materials, both as structural and non-structural materials. The use of bamboo in traditional houses is due to the fact that bamboo grows abundantly in tropical rain forest. But after industrial era has begun the use of bamboo as building material become obsolete. Bamboo is considered as cheap and non-permanent Bamboo naturally grows in the forest but also can be cultivated in plantation. While the largest stock of bamboo grows in forest, it raises some important questions regarding resource ownership and management (Jansen, 2000). Local community in Asia usually plant bamboo around their village. In some remote village, bamboo grove is used as a fence or as boundary layer for the village. In this case, bamboo belongs to the community and it is free to use by the community.

Figure 1: Distribution of bamboo worldwide
Jansen, J.J.A. (2000).

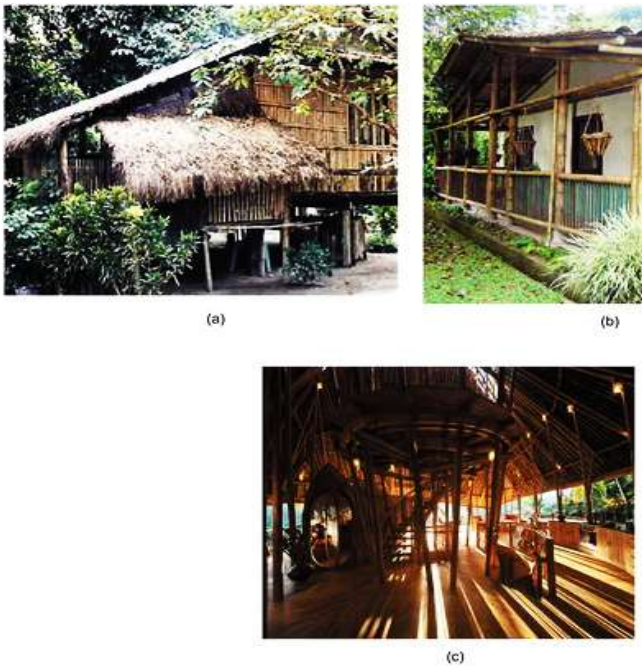

Figure 2- Jansen, J.J.A. (2000).

Bamboo could be used to make all parts of the house from structural walls and columns, to woven roofs to doors and windows (McClure 1981). In the olden times, bamboo was used in combination with other natural construction materials like wood, clay, lime and grass. Recently, it is used in combination with cement or adhesives to produce much stronger and

aesthetically pleasing materials that are compatible with modern lifestyle. As bamboo is a natural material, it is susceptible to natural degradation.

2. BAMBOO AND BAMBOO-BASED CONSTRUCTION MATERIALS

Bamboo has been used as a construction material due to its easy availability, ease of workability and its strength. Bamboo is stronger as a tensile member and it is recommended for use as horizontal members less than 3–3.6 m long without middle support (Nwoke and Ugwuishiwu 2011); potentially withstanding up to 3656 kg/cm2 of pressure (358.53 MPa) (Paudel 2008).Bamboo is a giant grass. It is an important non-timber forest product which has multiple uses for people. One of the most prominent uses of bamboo is in construction. Bamboo has been used as a construction material from ancient times, especially by people who live in places where bamboo grew naturally and abundantly. In ancient times bamboo was used to build houses because of its natural strength and flexibility. In the modern context the aesthetics of bamboo also plays an important role.

These composites are very homogeneous in quality and can be tested and calculated in the manner of timber constructions (Krötsch 2013; Lobovikov et al. 2007) and they have better strength and termite-resistant quality than untreated bamboo (Deka, Das, and Saikai 2003). Nowadays, these materials are also called biocomposites, and can be divided into three categories (Suhaily et al. 2013):

1.Conventional Biocomposite: Chipboard and Flakeboard, Plywood and Laminated boards, Medium Density Fiberboard, Hybrid biocomposites;

2.Advanced Polymer Biocomposite: Thermoplastic- based bamboo composites, Thermoset-based bamboo biocomposites, Elastomer-based biocomposites;

3.Inorganic-based biocomposites: inorganic binders – gypsum, portland cement and magnesia cement.

3. ORGANIC SHAPED IN ARCHITECTURE

Term organic architecture is introduced by Frank Lloyd Wright in his essay entitled “The Language of Organic Architecture”. Wright’s essay was actually to defend the idea of Louis Sullivan which was known as form follow function. Organic architecture term comprises a literal relation between a building and its environment, a building should integrate itself with its site .While organic shape term may have a slightly different meaning with organic architecture term. Organic form can be described as form that has been generated or created inspired by natural forms in nature. organically inspired structural systems typically exhibit interesting aesthetic qualities which are not necessarily intuitive .Adaptation of natural forms usually generates an irregular geometries.

The use of these materials and the advancement in the preservation of bamboo from natural pests like rot and fungi has given to development of beautiful yet daring architectural marvels for which innovative joinery/connection have been developed.

4. RESEARCH METHODIN

This study, case studies are needed to review the potential of bamboo as building material in organic shaped building. The objects of case studies are Green School, OBI Great Hall, Dodoha Mosintuwu and Bamboe Koening restaurant. The objects are selected because all of the objects

have unique form and organic shape moreover use specific structural system and construction method to obtain the organic shape. Research method is carried out through field study, literature review and by acquiring some information from the architect who designed the case study object.

5. EMBODIED ENERGY

Bamboo can be used as solid wood substitute materials, especially in manufacture, design and construction usage (Scurlock, Dayton, and Hames 2000; Bystriakova et al. 2003), decreasing the pressure on forest resources. It can also reduce the current trend of construction industry's use of high energy consuming building materials. Whereas the fabrication of bricks and cement consumes large quantities of energy and emits accordingly large amounts of carbon dioxide, the act of bamboo cultivation (which is sometimes called the act of growing architecture) is one of the best ways to reduce the green-house effect (Stamm 2001).

The objects are selected because all of the objects have unique form and organic shape moreover use specific structural system and construction method to obtain the organic shape. Research method is carried out through field study, literature review and by acquiring some information from the architect who designed the case study object. This research is limited to the aspect of form and formgiver, which is defined as structure and construction system to learn and observe the implementation of bamboo in organic shaped building.

6. ENVIRONMENTAL POLLUTION

Bamboo is considered to be environmentally friendly because it comes from a rapidly renewable resource (Gichohi 2014). The increase in bamboo use can help to reduce deforestation, encourage new and existing cultivators to grow more bamboo, utilize wasteland, unused land and river banks, which will result in better soil conservation and mitigation of flood disasters (Jianghua 2001; Nwoke and Ugwuishiwu 2011). From Sandaker opinion, it can be said that the use of materials in architecture should consider the character andproperties of the materials because materials play a role in generate a form.

7. COST OF MATERIAL

Bamboo is often adopted as a cheaper construction material alternative. Although this might be true in cases where bamboo is available locally, the transportation costs could significantly increase construction cost and its sustainability in places where bamboo is not grown. This is true in the case of European markets. However, in China, the bamboo industry has become a backbone industry in economic development and poverty alleviation of rural areas, and a new growth point of economy in remote mountainous areas of southern China (Jianghua 2001).

8 .ANALYSIS AND DISCUSSION

8.1Organic Shaped Buildings with Bamboo

Bamboo as building material is not constantly use into organic shaped building. The reference shape of bamboo building mostly come from wooden building which is generally constructed

using simple frame structure. Therefore, the builders tend to construct bamboo into frame structure thus becoming a box, static and, consider as boring,

Green School is a school building build using bamboo as main structure materials. Initiated by John Hardy, the school complex building finally won Aga Kahn award in 2010. The school building is located in Bali, Indonesia,designed in 2006 and completed in 2007. It is considered as the originator of bamboo revival in Indonesia. Even though bamboo is common building material in Indonesia, but, as mention before, due to the idea of bamboo as cheap and "poor man timber", bamboo potential and charm in creating unique building become submerged. Thus when a bamboo building is awarded by international organization and the design is being discussed by experts, people become aware to bamboo.

A qualitative study showed that it is possible to use bamboo for modest housing by using split bamboo as reinforcement by following the design for steel reinforcement concrete.

8.2Structural System of Organic Shaped Buildings with Bamboo

Architecture cannot be detached from form and architecture also requires structure to create form, without structure, the form cannot be achieved and only become a mere concepts. Structural system can be divided into form active, semi form active and non-form active structure systems. Form active structure is a structure system that only can withstand the axial forces, tension or compression. Bahareque consists of timber vertical elements and horizontal timber, cane or bamboo elements, with mud infill and finished with plaster

The surface structure of the main building, called as the heart of Green School, uses battens, rafters and purlins supported by bamboo pillars. The system resemble to the tent-like structure system. The circular purlins play a role in giving the nautilus shell shape to the roof. Meanwhile other smaller buildings are using combination of arches and surface structure.

8.3Construction Techniques of Bamboo for Organic Shaped Buildings

Organic shape buildings generally use arch, spline or other curvature shape. To achieve the form, it needs curve bamboo. There are two methods of bamboo bending according to Dulkenberg: hot bending method and cold bending method. Hot bending method can be done by immersing bamboo in the lukewarm water until the fibers are become soft enough to be curves using clamp; or by heating bamboo section to the desire heat (>150o) that cause bamboo fibers become soft and easy to bend. To bend bamboo in cold bending method can be done by splitting bamboo into planks then tie it into become a bundle; or by slashing bamboo rods the curved it. Bamboo bending method can produced smooth or segemented bamboo curved as well as can increase or decrease th strength of bamboo, differ to the method that is applied.

9. A Systemic Biomimicry Design Framework: Key Components And A Closed-Loop Learning Process

There is a rich and long history of gaining inspiration from nature for the design of practical materials and systems. From the early nineteenth century, architectural designers and engineers have started to imitate the forms, and develop new methods, analogous to the processes of growth and evolution in nature and to apply aspects of biological thinking in innovative designs in general (Steadman 2008). Researchers have also formed concepts around innovative biomimetic designs for building applications (Vogel 2009; Vincent 2009). A number of terms have been used to describe the process of learning from nature, and they are often used interchangeably, each with a slightly different focus or starting point. For example,

biomimicry promotes thinking of a building as a living entity (Benyus 2002). Biomimetics, on other hand, a term coined by Otto Schmitt in the 1950s, emphasizes the transfer of ideas and analogues from biology to technology (Schmitt 1969)

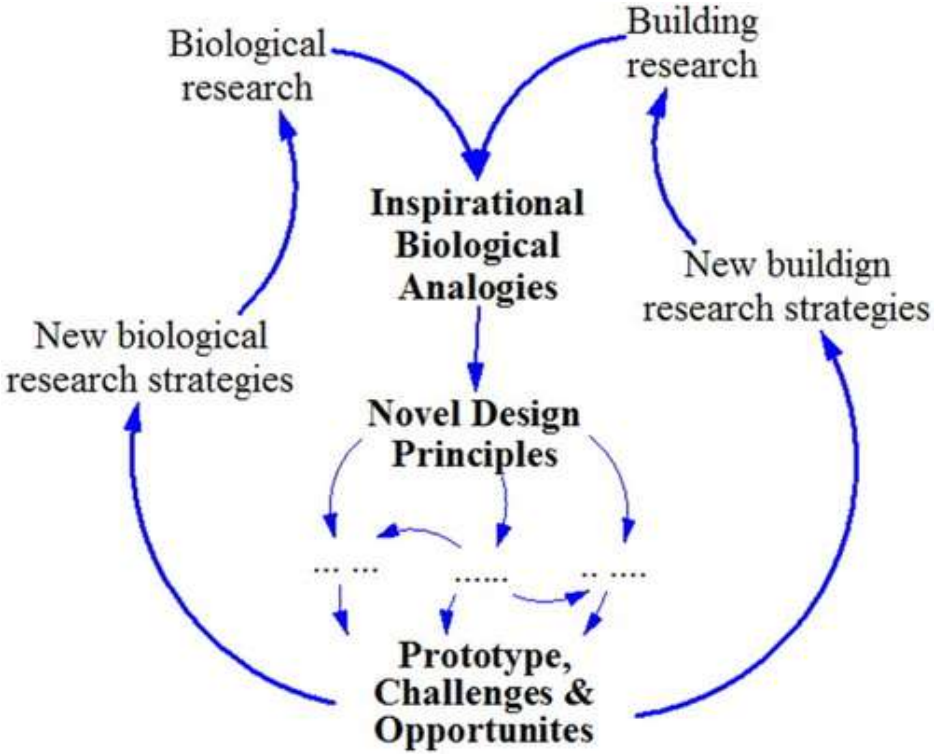

Figure 3:A systemic biomimicry design framework
Jansen, J.J.A. (2000).

10.STRUCTURE, COMPOSITE, FORM AND FUNCTIONS

10.1Plant cell walls: structure and composition

Our knowledge of plant cell walls is based on an in-depth understanding of its biosynthesis, structure and molecular physiology. In his Micrographia, Robert Hooke discovered plant cells: more precisely, Hooke had been viewing the cells in cork tissue and described them as an 'infinite company of small boxes' saying that 'these pores, or cells, were not very deep, but consisted of a great many little Boxes, separated out of one continued long pore, by certain Diaphragms' (Hooke 1665).

While in Bamboe Koening restaurant, bamboo splits are installed at the roof eaves to support rafters and form a twisting end of the roof. Bamboo split method is flexible and easy to construct. It can be used to create smooth curve even spline shape. However, bamboo split method can decrease the strength property of bamboo and can cause structural deformation and deflection (Maurina, 2015).

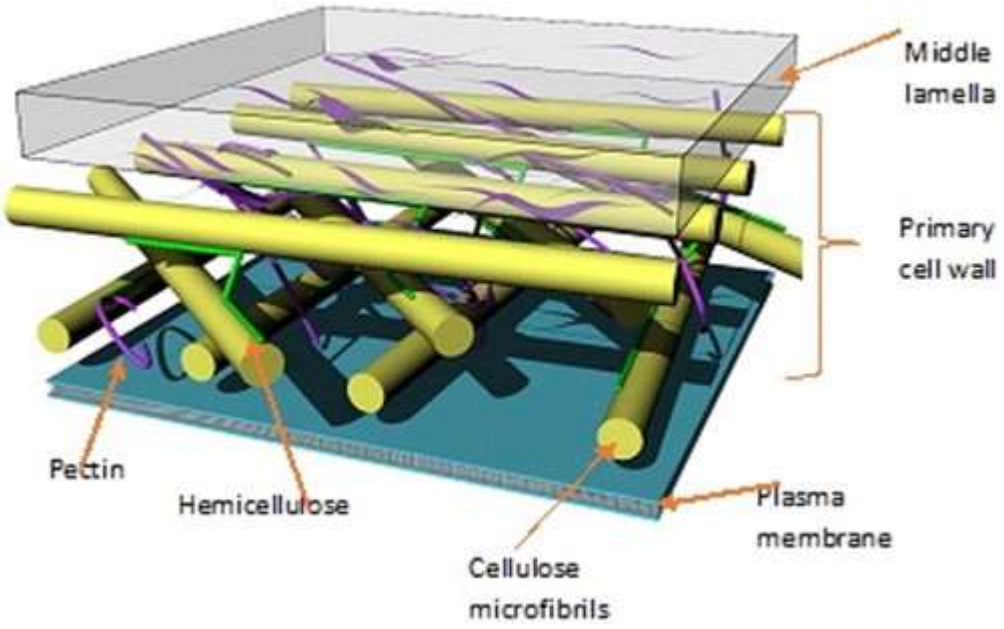

Figure 4: Highly simplified model of the primary plant cell wall
Jansen, J.J.A. (2000).

11. CONCLUSIONS

As per the survey it was found that the issues need to be tackled from various fronts in a systemic manner, since they are inextricably linked to each other. It is undoubtedly a marathon task. The project needs collaboration from the highest authorities to the lowest bodies to make it successful.

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