

USE OF BAMBOO BARS IN REINFORCED CONCRETE

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Abstract-Due to its wide use as a sustainable building material and some other reasons 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 lüthe. 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 bamboo can be a potential building material for organic shaped buildings and become an alternative building material other than steel and concrete.

Keywords- Joint system, sustainable building material, bamboo

INTRODUCTION

Bamboo naturally grows in the forest but also can be cultivated in plantation. The application of bamboo as a building materials has occurred in a long period. Most of the 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 materials. It is also considered as low-class material, even called as "the poor man timber" by many modern builder (Lobokivov, 2009). People tend to choose brick, concrete and steel as structural and construction materials for modern building. But nowadays, after global warming and sustainability issues are emerged, bamboo as building materials is widely discussed and reviewed. Some architect and builder nowadays tend to choose bamboo for building material. High-quality woods for construction are rarely found nowadays because of deforestation. Wood also takes long time to regrow and ready to use as construction materials. Meanwhile bamboo can be harvested in a short time, which is between 3-5 years. When planting, bamboo also releases oxygen into the air, the ability that cannot be performed by industrial materials like steel, plastic and concrete. For the reasons, bamboo has been widely known as sustainable building materials. 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.

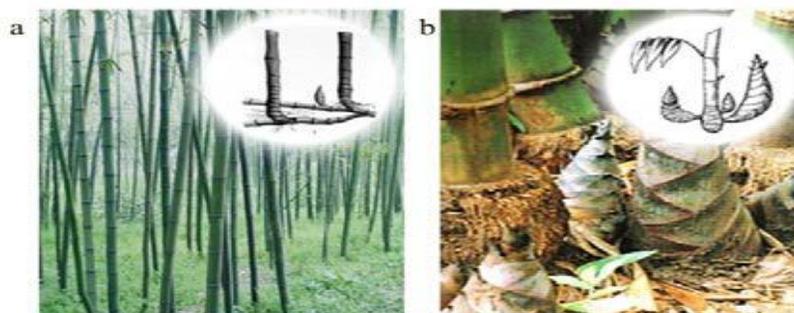


Fig. 1. (a) Monopodial bamboo; (b) Sympodial Bamboo

METHODOLOGY

In 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. This research is limited to the aspect of form and form giver, which is defined as structure and construction system to learn and observe the implementation of bamboo in organic shaped building.

Analysis and Discussion

3.1. Organic 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, simple form building. However, the study, research and exploration of bamboo as building material are being conducted by scholars, architects and builders. As a result, the evolution of building shape and form of building with has become more dynamic, moving and flowing. The strength and internal property of bamboo are studied. Bamboo are pushed to the limit to find what bamboo can do in building, what shape and form can be develop using bamboo, and what the suitable system is needed to design a unique bamboo building. 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. Green School building design has been through various stage of exploration in building form, structure system and construction process. The school complex consist of several masses which each mass accommodate different function such as classroom, laboratory, multifunction hall, office, student and teacher's dormitory, etc. Roofs are the most noticeable and prominent of the mass, each mass has different roof shape and it is organic shaped. The main hall is using arch shape located near the entrance gate. The main building, which is located in the center, is two to three storage building. The building has three circular shapes that resemble nautilus shell. The three nautilus shape roof is lined together formed wide envelope for the space below. While other smaller masses has varies roof shape and form. Not only the masses have organic shape but also the bridge which has hyper structure.

After Green School, various building using bamboo as building material is designed and built. If at first bamboo used in simple frame structure, nowadays bamboo is pushed to the limit and other structure systems are proposed. OBI Great Hall which is located in Jatiluhur, West Java province, Indonesia, is known as one of the phenomenal building using bamboo. Designed by Andry Widjowijatnoko, OBI Great Hall is an example of wide span building structure using bamboo. The oval shape plan is covered by combination of dome and hyper shape roof. The opening at the roof top creates a stunning and striking skylight. Along with the increasing popularity of bamboo to public, especially designer, the use of bamboo as building material began to be implemented in commercial buildings such as exclusive yet expensive resort hotel and restaurant. For example is Bamboe Koenig (yellow bamboo) restaurant in Lodayuh, Bali, which is recently received an award from Future Arc for using local material and worker. Designed by young architect, Effan Adhiwira, the restaurant has a circular plan with a circular stage in the center of the restaurant; therefore, the owner can perform a Balinese traditional dance on the stage. Its roof also has a circular and dynamic shape that make the building looks like a serpent. Another organic shaped bamboo building designed by Effan Adhiwira which also has an organic shape is a community building for community development project in Poso, Central Sulawesi (Celebes) province, Indonesia, namely as Dodoha Mosintuwu. This unique building is built on land that is flooded every rainy season thus the construction process is conducted on the dry season. It has dynamic and twisting roof shape combination of synclastic and anticlastic curvature. The synclastic curvature roof shape serves as an envelope for multipurpose hall while the anticlastic curvature roof shape is for daily activities space, such as office and library.



Fig. 2: Bamboo Reinforced bars

3.2 Construction Techniques of Bamboo for Organic Shaped Buildings.

The Arch, spline or other curvature shape are generally used in Organic shape buildings. To achieve the form, it needs curve bamboo. There are two methods of bamboo bending according to Dulkenberg: hot bending method and cold ending 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 segmented bamboo curved as well as can increase or decrease the strength of bamboo, differ to the method that is applied (Maurina, 2015). Bamboo split technique is used in Green School structure, especially as supporting arches in the smaller masses that are functioned as classrooms. While in Bamboe Koenig restaurant, bamboo splits are installed at the roof leaves 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). To prevent deformation and deflection of structural members, the sufficient dimension proportion to the span is needed.



Fig. 3. OBI Great Hall (a) Building form; (b) Interior, show the structural system



Fig. 4 Structural details; (a) Bamboo split method and bamboo bundling; (b) Bamboo split details; (c) Detail of arches using bamboo bundling.

CONCLUSION

The use of bamboo as building material in organic shaped building proved vastly potential because the nature and properties of bamboo are capable to accommodate it. Organic shaped building generally develop using form active structure system or semi form active system, although it is also possible to use non-form active structure system, i.e. trusses. There are several method that can be done to curve or bend the bamboo into desired shape, such as hot bending method and cold bending method. Beside hot bending and cold bending, curvature shape also can be generated by connected natural curve bamboo. Beside the understanding about the nature and properties of bamboo, the knowledge about structure system and bending method, the knowledge about joinery system is also needed.

However, the use of bamboo as sustainable building material still arise a question about the preservation method.

It is critical to observe and perform continuously research on effective and environmental friendly preservation method using minimal or without chemical ingredient to minimize negative impact to the environment. Therefore we can use bamboo in reliable and responsible manner.

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