

PRINCIPLES OF SUSTAINABLE ARCHITECTURE IN THE PRODUCTION OF BAMBOO WOVEN WALL MATERIALS (DENDROCALAMUS ASPER)

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Abstract -- Bamboo is a sustainable building material because the use of new materials is sustainable. In the City of Kendari, there are still craftsmen of bamboo woven wall material. This research is important to do because to reveal how to make bamboo woven wall material by local craftsmen in Kendari and to find out the pattern of making bamboo woven wall material against the principles of sustainable architecture. This research is aimed at identifying and reviewing work tools, work materials, and how to make bamboo woven wall material against the principles of sustainable architecture by local craftsmen in Kendari City. This study uses a case study method with a qualitative approach. This study concluded that the principles of sustainable architecture in bamboo woven wall materials are as follows: working tools are used simply to reduce the use of new materials, the materials for making come from vegetation grown so that the location and natural resource ecosystems are sustainable, and how to make use of human energy so that it saves energy.

Keywords: Sustainable Architecture; Bamboo Woven Wall

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INTRODUCTION

In the past three decades, the energy crisis and environmental damage have been the most important issues in the world. The energy crisis threatens human welfare and natural sustainability. The energy crisis encourages human consciousness to think holistically ecologically. This awareness movement grows in the form of sustainable development. This movement entered into all sciences, including its architecture and derivatives. Architecture is an important target of this movement. The condition happens because architecture produces buildings. The building consumes one-sixth the source of clean water, a quarter of natural wood and two-fifths of fossil fuel. Therefore there is sustainable architecture. Sustainable architecture is an idea of the concept of sustainable development in the field of architecture. Sustainable architecture is an architecture that can meet the needs of the present and think of the generations to come [1].

Sustainability has become important architectural issues today as concerns about depletion of natural resources, reuse of natural and synthetic materials, as well as conservation of nonrenewable energy resources, take on global proportions [2][3]. The basic challenge

underlying the idea of social housing is how to create adequate living conditions with minimal possible economic costs [4]. Sustainable architecture has principles, as follows: saving energy, considering local demographic aspects, coordinating with natural energy sources, minimal use of new materials, considering the location ecosystem and potential resources and considering the health of building users [5]. The implementation of sustainable architecture still has several obstacles, as follows: (1) the values of local wisdom contained by traditional buildings such as harmony and sustainability tend to fade [6]; (2) local demographic influences in the design process tend to be considered less so that additional energy is presented [7], and (3) awareness of building materials towards sustainable principles by architects tends to be low [5]. They are related to the statement that most of the energy waste in the world is in the building and its construction process. Thus, this situation encourages planners and designers to produce sustainable work. Another alternative solution to solve this problem is through bamboo local material [8].

Bamboo is a source of renewable and sufficient building materials available in Indonesia. Bamboo plants are spread all over

the world. Bamboo plants consist of 1,250 species, and 11% of them are found in Indonesia. This is one reason why bamboo plants are called local Indonesian plants. However, bamboo material has not become a development priority. Bamboo materials are still seen as informal building materials that are quickly damaged [9]. Bamboo material qualifies as a sustainable building material. Bamboo material is seen as an alternative economic building material. Bamboo material can be used as a structure and construction in housing. This is especially true for housing in developing countries. Bamboo materials can be made of structural and non-structural buildings. The material can be made of wall material and partitions. Bamboo woven wall material consists of structural frames. Bamboo woven wall material made from bamboo woven fillers. Fillers of bamboo woven wall material can make the construction sturdy and stable. Bamboo woven wall material is used to provide privacy and protect residents against rain, wind and animals. Fillers of bamboo woven wall material should be considered light and ventilated [10].

Based on data from the construction statistics in Indonesia from 1990 to 2010, the value of construction tended to increase. This means that the use of natural resources will be higher and the amount of construction waste will increase. If development is not managed properly, then there will be an environmental disaster in the future, so that the concept of sustainable development is needed. In Indonesia's 2030 construction documents, it is stated that Indonesian construction must be environmentally oriented. This can be traversed by the application of sustainable construction [11][12]. Each building is designed, built, operated and maintained for the health and well-being of residents. Buildings are also expected to have minimal negative impacts on the environment [10].

The categories of green building materials are as follows: (a) green building products are made from attractive environmental materials; (b) green building products can reduce environmental impacts during construction and renovation; (c) green building products can reduce the environmental impact of building operations; (d) green building products make the environment safe and healthy [10]. Energy waste is found in the building and its construction process. This encourages architects to be able to produce sustainable work. This can be traversed with local plants such as bamboo [8]. Nature and

environmental conservation can be applied to sustainable architecture, such as in the selection of building materials. The country of Indonesia has a vast diversity of building materials, such as bamboo plants. However, the innovation of bamboo in buildings tends to be low [14]. One of the innovations of bamboo material is bamboo plaster wall material. Plaster wall bamboo material has advantages compared to bricks, as follows: (a) the physical and mechanical properties of bamboo material is higher than that of red stone; (b) bamboo material has a lighter volume compared to wood; (c) bamboo material has a lower u-value than wood; (d) bamboo materials are more economical compared to bricks [15].

Bamboo woven wall material is more environmentally friendly than brick. This is because air can pass through the wall. Sustainable buildings are also called energy-efficient buildings [16]. Bamboo qualifies as an environmentally friendly building material (green building). Bamboo is seen as an economical material alternative. Bamboo material can be used as an alternative housing solution in developing countries. Bamboo has the potential as a material for housing and construction that is environmentally friendly, as follows: (a) bamboo material has high tensile strength compared to mild steel; (b) bamboo material has a high strength ratio and high load-carrying capacity; (c) bamboo material has low production energy; (d) bamboo performance services can be improved by preservation; (e) bamboo material can be formed by composite panels; (f) bamboo material has high residual strength and is suitable for use as building material; (g) Bamboo material can absorb carbon dioxide and contribute to the greenhouse effect [10].

Bamboo is a natural, versatile, renewable and sustainable material. However, the modern use of bamboo materials tends to be minimal [5]. Bamboo is a renewable and promising resource. This is because bamboo plants have high growth rates and easy processing. Bamboo growth only takes 3-5 years and can be used as a construction material. Bamboo material grows faster than wood. Wood must wait 10-30 years to be used as a construction material. Bamboo has good mechanical properties, low costs and is quite available in developing countries. Growth of fast bamboo plants and extensive root tissue, bamboo plants are used as carbon fixators, erosion prevention and water conservators. In the field of construction, bamboo material has a flexible, strong and easily cultivated character. Bamboo

plants are seen as alternative substitutes for wood [13].

Bamboo plants have great benefits for ecology and the environment. Bamboo plants produce 35% more oxygen than ordinary plants. Bamboo plants can produce a target amount of oxygen in an area. The target amount of oxygen can be achieved faster. This is due to the growth of bamboo plants faster than ordinary plants. Bamboo plants also absorb more carbon dioxide than ordinary plants. Bamboo plants can reduce 12 tons of CO₂ per hectare per year. Bamboo plants can increase the groundwater level and absorption of groundwater. Therefore, bamboo plants need to be utilized in areas that are difficult to water. Bamboo plants can also resist landslides compared to ordinary trees. This is due to the type of fiber bamboo roots such as coconut trees. Bamboo plants can be used as industrial forests. In Indonesia, bamboo plants are easily found because they are fast growing. Bamboo plants can be used as building construction materials at the age of 3-7 years. This is faster than wood from 10-30 years. Bamboo material has better strength than wood. Bamboo material has high tensile strength and compressive strength compared to steel and concrete materials. Therefore, bamboo material can be recommended as an alternative to building construction in Indonesia [17][18].

The biosphere on earth tends to experience a lack of resources. This shows that it is not sustainable. Architects and developers are expected to have knowledge of building materials that are restorative to the environment. In this case, bamboo material plays a key role. Bamboo is the fastest growing plant. Bamboo plants produce 30% more oxygen than wood forests. Bamboo plants can increase watersheds, prevent erosion and restore damaged land. Bamboo plants can also neutralize toxins on contaminated soil. Bamboo plants produce beam structures, floors, wall panels and fences. Bamboo materials produce many building products that are sustainable and can restore the environment. Bamboo stems can be harvested every year. Bamboo material has an annual biomass increase of 10-30% compared to 2-5% of trees. Bamboo plants produce 20 times more wood than ordinary trees. Selective bamboo plants are harvested every year and grow without replanting. Bamboo plants produce 30% more oxygen than ordinary trees and help reduce carbon dioxide gas.

Bamboo clumps can absorb 12 tons of carbon dioxide per hectare, and bamboo plants

become fresh air fillers. The bamboo root distribution system is extensive, so bamboo plants can reduce rainwater runoff and prevent soil erosion. Bamboo plants produce twice as much water in watersheds compared to ordinary trees. Bamboo plants can reduce water pollution. This is due to the high consumption of bamboo nitrogen. Therefore, bamboo is a nutrient absorption solution for excess wastewater. These wastes are agricultural waste, manufacturing, livestock and waste treatment [10]. Thus, bamboo is a sustainable building material because the use of new materials is minimal, the ecosystem of location and natural resources is sustainable and energy efficient.

In Kendari City, there are still craftsmen of bamboo woven wall material. This is due to the demand for high wall material. During this time, bamboo plaited wall materials are used as chicken coops, wall material of garden houses, kitchen wall material in community housing, cafe interiors, restaurant interiors, resort hotel interiors, custom equipment at a wedding party and others. This research is important to know the pattern of making bamboo woven wall material against the principles of sustainable architecture. This pattern is expected to be brought to the construction of the structure and construction of the present building so that building products that are environmentally friendly (sustainable) are created. This research is aimed at identifying and reviewing work tools, work materials and how to make bamboo woven wall material against the principles of sustainable architecture by local craftsmen in Kendari City.

METHOD

This study uses a case study method with a qualitative approach. The choice of this method is based on the objectives of the study.



Figure 1. Making bamboo walls

This research uses the object of research regarding the fabrication of bamboo woven wall material against the principles of sustainable architecture, as seen in Figure 1. Data collection is done by documentation. Table 1 showed the documentation is obtained by taking pictures of objects such as work tools, work materials, and manufacturing stages. The results of the research data are taken from previous studies such as the principles of sustainable architecture.

Table 1. Data requirement

Research Purposes	Variable I	Variable II
To identify and review work tools, work materials and methods for making bamboo woven wall material against the principles of sustainable architecture	The stages of making bamboo woven wall material Principles of sustainable architecture	Work tools, work materials, and manufacturing stages The use of new materials is minimal, location and natural resource ecosystems can be sustainable and energy efficient.
	The use of new materials is minimal, the location ecosystem and natural resources are sustainable and energy efficient.	Work tools, work materials, and manufacturing stages

Data analysis techniques are carried out as follows: (1) data collection; (2) data reduction; (3) presentation of data and; (4) concluding.

RESULTS AND DISCUSSION

Bamboo woven wall material made by Mr. Sapri. Mr. Sapri has been in this business since 1980. Mr. Sapri is now 77 years old. This business is located on La Ode Hadi (By Pass) Street, Bungguya village, Wuawua sub-district, Kendari city. Mr. Muhammad Yasin assists this bamboo matting business. Mr. Muhammad Yasin is Mr. Sapri's son-in-law. Mr. Sapri does not only sell bamboo woven walls but also sells woven walls of sago stalks, stick brooms, palm brooms, ceiling brooms, chicken cages, bamboo blinds, holy Bala (wedding traditional customs), ayu fence gates (traditional equipment marriage), greening basket and chicken coop. Mr. Sapri sells the best-selling products on the market, such as broomsticks and palm fiber brooms. Bamboo woven wall material is made when there is consumer demand. Bamboo woven wall material is made by being hit and irat. Mr. Sapri made bamboo plaited wall material using being impregnated. According to Mr. Sapri that the making of bamboo plaited wall material utilizing

impregnated is more aesthetically compared to being beaten. Work tools, work materials and methods for making bamboo woven wall material, as follows:

Work Tools

Bamboo woven wall material is made with work tools, as follows: (a) The machete is needed sharp and long. The machete is used to split bamboo; (b) saws are needed sharply. Saws are used to cut parts of bamboo segments. The sections are located at the end of the bamboo; (c) the hammer is used to tidy up and close the woven bamboo so that it is aesthetic; (d) the meter is used to measure bamboo. This is intended to get the right size, so the use of bamboo material is more effective. Simple work tools so that the use of new materials is minimal, as seen in Figure 2.



Figure 2. Work tools

Work Materials

Bamboo woven wall material is made with materials, as follows: (a) the color of bamboo material is needed in dark green; (b) bamboo material is needed with lengths of 4.20 m and 6.20 m; 3) Bamboo material needs a thin shape. This is intended to be easily formed and stronger. Work materials are sufficiently available and can be grown, so that location and natural resource ecosystems can continue as seen in Figure 3.



Figure 3. Work material

Manufacturing Steps

Selection of Bamboo

The choice of bamboo is based on size. Bamboo is minimized cutting so that all bamboo material is used. Bamboo is needed with a size of 4.00 m. If bamboo is obtained with a size of 4.20 m, then 20 cm is not used. Bamboo material is needed fat. This is intended so that the number of webbing is a lot. Bamboo is not fat produced a little amount of webbing. Bamboo materials were obtained from Wolasi, Nangananga, Landono and Konda villages. Bamboo materials from the village of Wolasi are better compared to other villages. The characteristics of bamboo are good, as follows: (a) the inside of the bamboo material is not runny. Watery bamboo is feared not aesthetic. This is due to the color of black bamboo;

(b) bamboo is needed thin. Thin bamboo segments when exposed to hard sunlight. Thick bamboo is found in soft sections, making it difficult to weave. Soft bamboo material easily attacked by insects; (c) bamboo age 1 - 1.5 years can already be woven. The length of the bamboo varies. The length of the bamboo is 4.20 m; 6.20 m; and 7.00 m. The long size of this bamboo is most often used to make bamboo woven wall material. Bamboo is purchased at a price of Rp. 600,000 (six hundred thousand rupiahs) per ret per car. One car obtained 200 (two hundred) bamboo sticks, and d) bamboo material consists of green and yellow. Green and yellow bamboo is best used as woven material. Green bamboo color is easily solved. This type of bamboo is well used as wall material. Wall material is made by beating.

Cutting the Bamboo Section

Bamboo is cut into sections with a saw. The section is located at the bottom of the bamboo. Cutting is intended to facilitate workers in splitting.

Bamboo Measurement and Bamboo Section Cleaning

This stage requires high accuracy. This stage also gets sales profits. Cutting bamboo material is needed for saving material. The length of the bamboo is 4.00 m and a bamboo woven wall material produces the number of bamboo 5 stems. Bamboo woven material is produced with an area of 1.50 m x 1.50 m. The remaining bamboo cuts were 1.00 m. The remaining pieces of bamboo are not removed but are used as curtain material. The bamboo length is 4.50 m and the number of 4-stem bamboos is produced by bamboo woven wall material with an area of 1.50 m x 1.10 m. The remaining bamboo cuttings were obtained 1.40 m and not discarded. The remainder of the cutting is used as curtain material. 6.00 m long bamboo is more profitable. The size of this material is made of woven bamboo walls 2.00 m x 2.00 m. The remainder of the bamboo cutting is used as curtain material and the material for short woven bamboo walls.

Bamboo material is cleaned every section with machetes. After that, bamboo is measured with broken bamboo. These pieces of bamboo have been woven and are used as measuring instruments. Bamboo fragments measuring 1.10 m and 1.50 m. The size of the material for woven bamboo varies. Size variations are adjusted to consumer demand. Bamboo woven wall material has a size of 1.50 m x 1.50 m, 3.00 m x 2.00 m and 1.60 m x 1.60 m. The best-selling bamboo woven wall material is sold at a size of 1.60 m x 1.60 m. The process of irrigation is needed bamboo that is smooth and clean. Bamboo is cleaned every segment with a machete. The cleaning process is carried out before the bamboo is cleaved. Cleaning bamboo is intended to facilitate irritation. The segment is the circular part and divides the distance on the bamboo.

Bamboo Cleavage

Bamboo material is divided by the following methods: (a) bamboo is measured and divided into two parts; b) two parts of bamboo, each split into 7-8 pieces of bamboo. So, bamboo has sixteen fractions; c) bamboo fragments are made by slicing.

Slice (Irat) of Bamboo

Irat is the process of splitting bamboo fragments. Obviously it is done by cutting the bamboo into two parts. Process of using a machete. *Irat* process produces two pieces of bamboo. Two pieces of bamboo are given the name of the heart and skin. The heart is the bottom of the bamboo and is white.



Figure 4. (a) The process of splitting bamboo wood and (b) The process of slicing bamboo fragments.

The skin is the surface of the bamboo and is green. Skin and heart are used as wall plaiting material. The skin and liver have a thickness of 0.1 mm, as seen in [Figure 4](#).

Bamboo weaving

The process of rowing should be considered several things, as follows: (a) the weaving process is carried out alternating system; (b) bamboo weaving is done by squatting. Squatting is needed to weave faster; (c) body position adjusted to webbing; (d) the first stage is woven, the webbing is made at a 90-degree angle; (e) horizontal weaving starting from the top end and going down 20 cm long; (f) locking each part of the sides of the webbing with one bamboo stick. Bamboo fragments are required to be rather hard. This is done so that the webbing is not uncovered; (g) wall weaving is done with a skin pattern - heart - skin - heart. Bamboo woven wall material is better to use all skin parts.



Figure 5. The process of weaving bamboo walls.

This process is better because the walls tend to be more durable. Bamboo woven wall material uses the liver and skin more often. This is done because of economic factors; (h) the skin and liver are separated; (i) four rows of skin and heart. This is done so that it is faster in the weaving process. The weaving of the skin and

heart are made in two lines. Weaving is not done three lines because of the long weaving process as seen in [Figure 5](#).

The process of weaving bamboo woven wall material is carried out in the following manner: (a) the first skin is arranged vertically on the work floor; (b) the second skin is arranged horizontally under the first skin; (c) the third heart is arranged vertically under the second skin; (d) the fourth heart is arranged horizontally under the first skin and the third heart ([Figure. 4](#)); (e) the fifth heart is arranged horizontally above the first and third skins; (f) the sixth heart is woven in circles so that an angle is formed; (g) the liver and skin are mounted vertically with alternating systems. After the woven corner has been formed and the plait has arrived at the end of the bamboo shards, then the webbing is locked with the skin. The skin is needed rather hard; (h) skin and liver are woven horizontally. The weaving process must be carried out until it reaches the end; (i) beating (skin and heart) should be beaten frequently. It is beating using a hammer. It is intended so that the webbing is neat and tight so that it is aesthetic; (j) woven sides are locked with rather hard leather. Locking is the last process; (k) the woven bamboo wall material has been finished and measures 1.50m x 1.10m. The manufacturing stages are done manually and use human power so that it is energy efficient as seen in [Figure 6](#).



Figure 6. Material of woven bamboo walls that have been finished.

Bamboo woven wall material has advantages, as follows: (a) material of bamboo woven walls do not need to be given the color of paint so that it is unique and artistic. If the wall wants to be colored with paint, the wall is given enough wall paint; (b) the age of bamboo woven walls reaches up to tens of years; (c) the walls are adequately installed with casso blocks so that they are effective; (d) the wall does not need to be dried in direct sunlight, but directly displayed;

(e) new woven bamboo wall material made quickly dry; (f) bamboo woven wall material is more waterproof compared to the material of woven sago skin walls; (g) bamboo woven wall material can be used as a ceiling and facade easel cover; (h) bamboo woven wall material is easily formed; and (i) material for woven bamboo walls is sold at economical prices.

Bamboo woven wall material has weaknesses, as follows: (a) bamboo woven wall material needs to be avoided from water. Water can make the walls easily weathered. So, the material of bamboo woven walls is more appropriate to be used as the interior walls of the house. If it wants to use it as an exterior wall, special treatment should be done. Bamboo plaited wall material is installed with a rafter beam. rafter beams are installed with a distance of one square meter each. The installation of rafter beams is intended for stable walls; (b) bamboo material is too simple, so for some people, it is considered unattractive. Bamboo woven wall material made by Mr. Sapri tends to be stagnant, not creative and innovative; (c) bamboo material entrepreneurs tend to be less fostered by the local government; (d) bamboo woven wall material is only used by the local Kendari community. Bamboo material is not sent outside of Kendari city; (e) walls made by squatting so that it is difficult for older people to do so; (f) bamboo woven wall material requires precision in the weaving process. If not careful, it will produce a wall that is not aesthetic.

CONCLUSION

This study concluded that the principles of sustainable architecture in bamboo plaited wall material are as follows: simple work tools so as to reduce the use of new materials, making materials come from vegetation grown so that the location and natural resource ecosystems are sustainable, and how to use human energy to save energy. Bamboo woven wall material can be mixed with mortar. This research can be continued with the incorporation of bamboo woven wall and mortar material so that it can be used as a material for sustainable public housing in Kendari City.

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