Bamboo Green Materials for Environmental Sustainability Constructions

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Abstract: Global warming causes an increase in average temperatures on Earth. Over the past decade there has been 13 million ha / year deforestation. South America and Africa experienced the highest deforestation rates (> 3.4 million ha / year) and Asia also experienced forest loss in many places. To restore the preservation of the forest is needed plants that grow fast and able to absorb more carbon than crops. Bamboo is known as one of the fastest growing plants in the world, with growth rates ranging from 30 to 100 mm per day in its infancy. Due to the rapid accumulation of biomass and the effective fixation of solar and carbon dioxide energy, the carbon sequestration ability of bamboo tends to be second to none compared to other plants. According to estimates, a quarter of the biomass in the tropics and a fifth in the subtropical region comes from bamboo. For the construction materials the effect of bamboo treatment on bamboo mechanical properties requires further assessment. Testing mechanical properties is done after the specimen on the dry conditions of the furnace. Water content of specimens in the range of 12 - 13% in accordance with ISO 3129-1975 standards. Analysis of Variance (Anova) bamboo treatment with lateral stress as a construction material has an effect on bamboo mechanical properties. In strong bending, tensile strength and bamboo shear strength with lateral stress up to 2.5 MPa have no significant effect on bamboo properties. While on Eastic Modulus of Elasticity and bamboo compressive strength with lateral stress up to 2.5 MPa have significant effect on bamboo properties.

1 INTRODUCTION

Global warming causes an increase in average temperatures on Earth. An increase in average air temperature of the earth's surface is less than 1 degree Celsius or 1.3 degrees Fahrenheit in the last 100 years. Increasing global warming severity is also caused by deforestation. While the oceans are no longer able to store carbon as they had in the past. Burning fossil fuels such as natural gas, coal, oil and gasoline increases the carbon dioxide levels in the atmosphere, and carbon dioxide is a major contributor to the greenhouse effect and global warming. Climate change will increase the number of people suffering deaths, illnesses and injuries from catastrophic waves, floods, storms and droughts. Major storms and floods have occurred in the last two decades (Venkataramanan, 2011). Since 1880, global warming has accumulated in water, soil, and water. During the same period, heat is released into the atmosphere by the use of fossil fuels and nuclear power. This thermal pollution contributes to heating. The accumulated and emitted heat ratio shows that heat emissions 55% of global warming (Gervet, 2007).

Forests are huge carbon stocks and biodiversity that must remain intact to control global warming and preserve life on earth. Over the past decade there has been 13 million ha / year deforestation. South America and Africa experienced the highest deforestation rates (> 3.4 million ha / year) and Asia also experienced forest loss in many places. In general, the causes of deforestation are infrastructure development, agricultural land expansion, land tenure, lack of adequate oversight by the government, high demand for timber, settlement expansion and mining. Increased international demand for plantation commodities can also affect deforestation. The resulting impacts of deforestation include changes in rainfall that have an impact on increasing the risk of forest fires during the dry season and the negative changes in the water and river basin levels, a huge loss of biodiversity as more than half of the animals and plants that live on

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the earth depend on forests . Deforestation dramatically affects the human population living in the forest. Indigenous peoples and traditional communities that are natural forest guards have seen their territories have been reduced or attacked by deforestation actors (Paulo, 2012).

The polemic on the environmental sustainability globally has risen significantly over the years from the Stockholm Conference on the Environment in June 1972 to the Earth Summit in Rio de Janeiro in June 1992 onwards, having decided on international action through the Framework Convention on Climate Change for reducing carbon dioxide and global warming on earth. In general there are three carbon inventories: oceans, atmosphere and terrestrial ecosystems. In terrestrial ecosystems, forests are able to store the largest carbon and store 1146x1015 g of carbon that occupies 56 percent of total carbon in terrestrial ecosystems. The bamboo forest ecosystem is an important part of the forest ecosystem and an important carbon source and carbon sink on earth (Li, et al., 2003).

To restore the preservation of the forest is needed plants that grow fast and able to absorb more carbon than crops. Bamboo is known as one of the fastest growing plants in the world, with growth rates ranging from 30 to 100 mm per day in its infancy. Can grow to a height of 36 m with a diameter of 1-30 cm (United Nations, 1972). Considering the characteristics of bamboo, so its the fastest growing and renewable natural resource (Lessard and Chouinard 1980).

Bamboo is the fastest growing plant in nature (Alfonso, 1987); there are more than 70 genera and more than 1000 species in the botanical literature, (Anon., 1988). They grow in sub-tropical zones especially on sandy topsoil up to clay mud. This plant can adapt to a short life cycle. The growth of bamboo stems is amazingly fast, about 70 mm daily and can reach 350-450 mm. The development of the trunk is completed within 4-6 months, Wong (1995) states that the bamboo stem takes only 2-6 years to mature depending on the species. Bamboo rods are generally cylindrical and smooth, with diameters ranging from 29 to 300 mm, 60-70% of bamboo is made up of fibers, and the fiber substance is more prominent at the edges than inside. The average height of bamboo is about 100 times its diameter (Atanda, 2015).

Bamboo plants can grow rapidly which only takes about four years to reach adulthood, compared with timber plants and fruits that take a long time to reach adulthood. In addition, in terms of carbon dioxide absorption, bamboo absorbs more carbon dioxide than wood or fruit trees. One hectare of bamboo plants can absorb more than 12 tons of carbon dioxide in the air. This is a considerable amount. By preserving the bamboo forests, we have already had a large carbon dioxide suction machine (Raka, et al., 2011). Bamboo forests are an important type of forest in many countries, especially in East and Southeast Asia and in African countries. Bamboo is versatile not only in its utilization but also for environmental protection. There is an old saying "bamboo is the wood of the poor", it shows its status in people's lives in the alleviation of poverty and the preservation of rural nature. Bamboo has great potential in soil erosion control, water conservation, land rehabilitation and carbon sequestration (Zhou, et al, 2005).

Bamboo is a giant grass in the Bambusoideae family, shell-shaped, orthotropic, high-strength longitudinal direction and low-power transverse direction. The distribution of fiber varies along its thickness. Fiber on bamboo is concentrated more closely on the outer shell (Pic. 1), as the endurance of wind gusts during its growth (Ghavami, 2008).

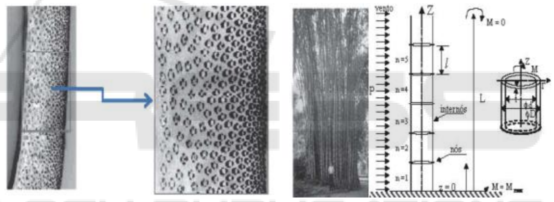

Figure 1: Bamboo Structures (Ghavami, 2008).

2 LITERATUR REVIEW

In tropical rainforest, bamboo spreads freely with still disruption of logging and forest encroachment. Bamboo is the fastest growing plant, reaching its peak in two to four months, and branching begins as soon as the stem reaches its optimum height. It is estimated that bamboo clumps can develop in its lifetime produce up to 15 km from the center grow with the diameter of the stem can reach 30 cm. So bamboo is very strong and dynamic in its growth. Due to the rapid accumulation of biomass and the effective fixation of solar and carbon dioxide energy, the carbon sequestration ability of bamboo tends to be second to none compared to other plants. According to estimates, one quarter of the biomass in the tropics and one fifth in the subtropical region comes from bamboo (Anonymous, 1997). Approximately 80% of bamboo-containing areas are located in tropical regions of South and Southeast

Asia, most likely contributing significantly to the world's carbon sequestration by bamboo (Zahou et al., 2005).

Bamboo leaves that fall under the bamboo is able to keep the soil moisture. Thick bamboo sheets help absorb and retain moisture more effectively, and reduce evaporation of water from the soil surface. Bamboo leaves also help increase soil organic content. Bamboo waste has a high water retention capacity. With respect to soil moisture, bamboo can withstand 2.75 times more weight than its own dry weight (Huang et al., 1997). *Dendrocalamus latiflorus* density with a density of 825 cigarettes per hm2, has the capacity to absorb moisture from 2.7 to 2.9 times the dry weight. The maximum forest holding capacity with *Phyllostachys pubescens* mixed with *Cunninghamia lanceolata* can reach 21.29 $t.hm^{-2}$, much higher if only *Cunninghamia lanceolata* reaches 7.37 $t.hm^{-2}$ (Chen, 2000). The same conclusion has been generated by other researchers (Wu, et al., 1992; Zheng, et al., 1995; Zeng, et al., 1998; Zheng, 1998; Lin, 2002).

Bamboo has thick green leaves and thick clumps that can help withstand large amounts of rainfall. A study in China proves that bamboo clumps can hold up to 25% of rain that falls directly to the soil surface, a value much higher than conifers and pines. The interception of clumps depends on the quantity of rods and the index of leaf area (Wu et al., 1992). Sympodial bamboo also has a high interception capacity. Zhou, et al., (2005), states the interception of rainfall in *Dendrocalamopsis latiflorus* forest in South China. Interruption of bamboo clumps each year is 128.1 mm for bamboo forest with media spacing of 3 m x 4 m, 6 stems in each clump and an overall density of 5,000 stems per hectare. And the interception ratio was 14.5%, with a runoff coefficient of 7.47%. It was found that the interception of bamboo clumps has a positive correlation to the density of clumps with total rainfall.

Roots and bamboo rhizomes underground can form like a woven mat that is effective in holding the soil. The soil around bamboo plants is absorbed by intertwined roots. Many studies show that most 80% bamboo rhizomes and roots are present at 0-30 cm of topsoil, ie areas where roots and rhizomes work best in controlling soil erosion. The bamboo species studied in this aspect are *Phytlostachys pubescens* (Xiao, 1983; Wu, 1984; Zhou, et al., 1985; Wang, et at., 2000), *Pseudosasa amabilis* (Chen, 2002), *Phytlostachys praecox* (He, et al., 1995; Hu, et al., 1994), *Qiongzhuea tunffdinoda* (Dong, et al., 2002), *Phyllostachys makinoi* (Huang, et al., 1994), Phyllostachys bissetti (Zeng et al. 1998), *Dendrocalamus latiflorus* (Lin, et al, 2000), *Dendrocalamopsis oldhami* (Linet, al., 1998) dan *Bambusa tulda* (White dan Childers, 1945). The roots and rhizomes of bamboo though grow shallow in the ground but horizontally widen. *Bambusa tulsa* roots, simpodial bamboo species with short rhizomes can extend horizontally up to a distance of 5.2 m (White and Childers 1945). For monopodial species with pervasive rhizomes, the total length of rhizomes per hectare in *Phyllostachys heterocycla*, *Phyllostachys viridis* and *Phyllostachys nigra* respectively range from 50 to 170 km, 90 to 250 km and 200 to 320 km (Xiao 2002).

Bamboo plants are very useful for controlling soil erosion. Able to grow well on steep hillsides, embankments, ditches, or on the banks of lakes and rivers. In the Hakoneama Mountains of Japan, the bamboo groves of Sasa and Indocalamus are scattered in mountainous areas with an altitude of 1000 m asl. In Brazil introduced *Bambusa blumeana* and *Phyllostachys pubescens* to control soil erosion, prevent the loss of soil nutrients and improve soil structure (Fu, et al., 2000). The advantages of bamboo in controlling soil erosion are its broad fibrous root system, interconnected rhizome system, leafy leaves that can be produced on the soil surface, its relatively dense foliage protects from high rainfall, and always produces new stems from underground and rhizomes that allow harvesting without damaging the soil (Zhou, et al., 2005). Erosion is one of the most severe types of soil degradation, which causes the loss of topsoil and greatly threatens the productivity of the land. The Puerto Rican researchers experimenting with several species of bamboo found that bamboo is one of the most effective in controlling erosion. Bamboo commonly used for erosion control purposes is the *Bambusa vulgaris* species (White and Childers 1945; Anonymous 1997).

In Japan for erosion control purposes, bamboo is generally grown in special places that are susceptible to erosion. In southwestern Japan, bamboo is widely grown in coastal areas overlooking the Pacific Ocean. Particularly in Kagoshima prefecture, it has been used as a protective web of hill erosion, a kind of hedge fence called "Karami" for erosion control for over 100 years (Shibata, et al., 2002). In China, about 90% of bamboo forests are naturally located upstream of rivers, lakes, reservoirs, or along the banks of rivers. The bamboo forest area accounts for 5% of the total forest area in the Yangtze basin, 4.5% in the Pear river valley and 2.5% of the Huaihe River basin (Li, 1998). Bamboo forests have played an important role in protecting the river banks. In the Dayingjiang river in Yunnan province and Jiulongjiang river in Fujian province, bamboo has succeeded in protecting the river banks after efforts with tree planting failed to protect the river banks (Anonymous, 1997; Fu, et al., 2000).

In the last five decades or so, 1,2 billion hm^2 of land (11% of the total land vegetation) was reported to have been degraded as far as their original biotic function was damaged (Oldeman, et al., 1990). According to a UNEP report (1992), at least a quarter of agricultural land degradation is caused by humans (agricultural practices, overgrowing, deforestation, etc.). With green bamboo shoots, large biomass accumulation, and abundant litterfall, bamboo has played a major role in the rehabilitation of degraded lands. In China, India and Thailand, appropriate bamboo agro-forestry models for planting in degraded lands have been developed. In China, three types of bamboo-agroforestry models have been established, which include an agro-silvicultural system (bamboo + tea, bamboo + wood needle or broadleaf, bamboo + food crop), silva-pastoral system (bamboo + fish or poultry) and special agro-forestry systems (bamboo + edible fungus and bamboo + medicinal plants) (Fu, et al., 2000).

From the literature study can be stated that bamboo can reduce the effect of global warming. Bamboo is very environmentally friendly so the use of bamboo as green material for kontsruksi is very important to do. At the age of 5 - 6 years bamboo stems can be harvested continuously without the need to plant again because of the growth of fast growing bamboo shoots.

3 PROBLEM IDENTIFICATIONS

At this time the timber with good quality has been difficult to obtain, so the wood is increasingly rare for building construction. However, the wood will be needed because it has several advantages over the baton and steel. The advantages of wood of which have good mechanical properties, where in the weight ratio of the power compared to a higher kind than concrete and steel in addition to approaching the renewable nature and aesthetics (Yasin, et al., 2015). To reduce deforestation due to logging for construction materials, it is time to replace wood with bamboo. Bamboo has a good strength when used properly for construction.

Bamboo fiber has a high tensile strength (Ghavami, 2005). Tensile strength bamboo fiber ranging between (150 - 320) MPa, greater than the tensile strength of wood fibers ranges (34 - 220) MPa. Parenchyma sell structures more dense with age bamboo, the bamboo optimum density occurs in 4 years old (Li, et al., 1995). Describes the use of bamboo which is divided into a traditional bamboo (conventional) and bamboo engineering (experience the manufacturing process) (Xiaohong and Yuloin, 2005). Morisco (2006), examined the tensile strength of bamboo parallel fibers without the nodia of the *Bambusa arundinaceace* skin much larger than the tensile strength of the reinforcing steel, and the tensile strength of the bamboo fiber in all the thickness of *Dendrocalamus asper*.

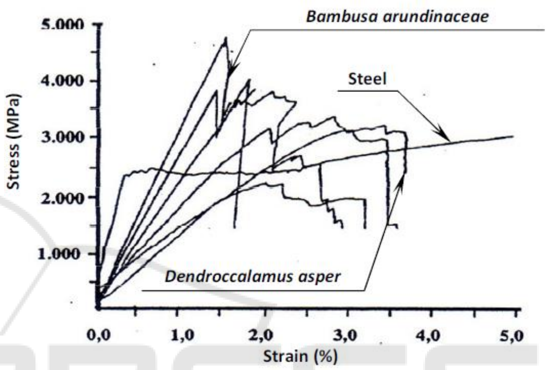

Figure 2: Bamboo Stress-Strain Graphic (Morisco, 2006).

Abundant supply of bamboo is abundant, its use is very effective and efficient, because cheap and easy to train in processing / processing, do not require many personnel and conventional method used (Hermanto et al., 2010). For the construction materials the effect of bamboo treatment on bamboo mechanical properties requires further assessment.

4 OBJECTIVES

Bamboo as a green material can reduce the effects of global warming needed for the sustainability of the environment and the earth is back green and comfortable as a place of human life and nature. This study aims to determine the mechanical properties of bamboo affected by the treatment during construction. The treatment of bamboo material in this study is the effect of pressure. Because in the construction process to obtain the desired shape, bamboo get pressure treatment, either the pressure of the laminate on the bamboo, or the pressure due to be hit at the time of grafting, etc.

5 METHODOLOGY

The research material is bamboo *Dendrocalamus asper* 5 years old originating from Purwobinangun Slema region of Yogyakarta Special Province region. The bamboo plants on the slopes of Mount Merapi are thriving so as to become the bamboo supplier of *Dendrocalamus asper* in the area around Yogyakarta. The bamboo portion is selected to obtain bamboo blades with an average thickness of 10 - 15 mm and the blade width averaging 35 mm. The size and shape of bamboo test object mechanical testing based on ISO 3129-1975 includes compressive strenght specimens, shear strenght specimens, tensile strenght specimens and modulus of elasticity specimens.

Table 1: Specimen Mechanical Properties Testing of *Dendrocalamus asper*.

No	Mechanical Properties of Speciment	Without Lateral Compression	With Lateral Compression (MPa)		
			1.5	2	2.5
1	Compression Strength	10	10	10	10
2	Shear Strength	10	10	10	10
3	Tensile Strength	10	10	10	10
4	MoE	10	10	10	10

Mechanical properties testing were done after the specimen on the dry conditions of the furnace. Water content of specimens in the range of 12 - 13% in accordance with ISO 3129-1975 standards. Testing specimens were done using Universal Testing Machine (UTM).

6 RESULT AND DISCUSSION

Anova calculation for bending strength on bamboo base material with 1.5 MPa pressure resulted F_{count} = 1.008 (less than F_{table} = 4,41) and probability value 0,342. At the pressure of 2 MPa fitting yield value F_{count} = 0.896 (smaller than the value F_{tabel} = 4.41) and probability value 0.371. At the pressure of 2.5 MPa fitting yield value Fcount = 0.0002 (smaller than the value F_{table} = 4.41) and probability value 0.988. This means that the pressure variation of up to 2.5 MPa does not give a significant difference to the bending strength of the bamboo base material, in other words that the pressed pressure up to 2.5 MPa has no significant effect on the bending strength of the bamboo base material.

Calculation of anova for MoE on bamboo base material with 1.5 MPa pressure resulted F_{count} = 0,934 (less than F_{table} = 4,41) and probability value 0,362. At the pressure of 2 MPa fitting yield value F_{count} = 0.284 (smaller than the value F_{table} = 4.41) and probability value 0.608. At the pressure of 2.5 MPa fitting yield value F_{count} = 6.140 (greater than F_{table} value = 4.41) and probability value 0,038. This means that the pressed pressure variation up to 2 MPa does not give a significant difference to the MoE of bamboo base material, in other words that the pressed pressure up to 2 MPa does not give significant effect to the MoE of bamboo base material. While the pressure of 2.5 MPa has a very significant effect on the basic material of bamboo so that 2.5 MPa pressure gives a significant effect on the basic material of bamboo.

The calculation of anova for tensile strength on bamboo base material with 1.5 MPa fitting pressure yields F_{count} = 5,251 (greater than F_{table} = 4,41) and probability value 0.051. This shows that the pressure of 1.5 MPa has a very significant effect on the tensile strength of bamboo base material so as to give a significant effect on the tensile strength of bamboo base material. At the pressure of 2 MPa fitting yield value F_{count} = 0,048 (smaller than value F_{table} = 4,41) and probability value 0,831. At the pressure of 2.5 MPa fitting yield value F_{count} = 1.283 (smaller than the value F_{table} = 4.41) and probability value 0.290. This means that the variation of the pressed pressure up to 2 MPa and 2.5 MPa pressure does not give a significant difference to the tensile strength of the bamboo base material, in other words that the pressed pressure up to 2 MPa and 2.5 MPa has no effect significant to tensile strength of bamboo base material.

Calculation of anova for shear strength on bamboo base material with 1.5 MPa fission pressure yields F_{count} = 0,301 (less than F_{table} = 4,41) and probability value 0,597. At the pressure of 2 MPa fitting yield value F_{count} = 0,006 (smaller than value F_{table} = 4,41) and probability value 0,942. At 2.5 MPa pressure, F_{count} value = 0,4002 (less than F_{table} = 4,41) and probability value 0,545. This means that the variation of the pressed pressure up to 2.5 MPa does not give a significant difference to the shear strength of the bamboo base material, in other words that the pressed pressure up to 2.5 MPa has no significant effect on the shear strength of the bamboo base material.

The calculation of anova for compressive strength of perpendicular fiber on bamboo base material with 1.5 MPa fitting pressure gives F_{count} = 0,232 (less than F_{table} = 4,41) and probability value

0,643. At 2 MPa fission pressure yields F_{count} = 1.617 (less than F_{table} = 4.41) and probability value 0.239. At 2.5 MPa pressure, F_{count} = 4,874 (greater than F_{tabel} = 4,41) and probability value 0,058. This means that the variation of the pressed pressure up to 2 MPa does not give a significant effect on the compressive strength of upright bamboo fiber material, in other words that the pressed pressure up to 2 MPa does not give significant effect to the compressive strength of the bamboo fiber. While the compressive strength of the bamboo fiber upright at the pressure of 2.5 MPa gives a significant difference in effect so that 2.5 MPa felting pressure gives a significant influence on the compressive strength of the bamboo fiber base perpendicular used.

7 CONCLUSIONS

Bamboo has great potential in reducing the impact of global warming. With the ability of bamboo in the control of soil erosion, water conservation, environmental conservation, land rehabilitation, and ability in carbon sequestration provide a promising future of life on earth. Bamboo forests are important to replace wood as a construction material of the future.

Analysis of Variance (Anova) bamboo treatment with lateral stress as a construction material has an effect on bamboo mechanical properties. In strong bending, tensile strength and bamboo shear strength with lateral stress up to 2.5 MPa have no significant effect on bamboo properties. While on Eastic Modulus of Elasticity and bamboo compressive strength with lateral stress up to 2.5 MPa have significant effect on bamboo properties.

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