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Characteristics of Bamboo Fiber as Environmentally Friendly Material for Soil Strengthening

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***Abstract*—Indonesia is a bamboo producing country. Many benefits that can be taken from bamboo trees, one of them is as an alternative construction material that is environmentally friendly and economical. Bamboo can be used in construction because bamboo has high tensile strength, it can be for the reinforcement of soil based on properties the mechanical strength. There are various types of bamboo and there are similarities between the bamboo fiber and other so it will be difficult to distinguish the type of bamboo that is good quality and less one because the human assessment is subjective.**

In this study for testing of fiber strength and bamboo fiber content we used the SNI 01-1840-1990 rule to test the fiber length, SNI 0492 - 2008 for Lignin test method using Klason Method, ASTM D1104 - 56 (1978) for method of test for hollocellulose in wood, SNI - TAPPI T 203 for the test of alpha, beta and gamma cellulose levels.

The result and analysis of fiber content, fiber length, intercellular adhesive of lignin and diameter of bamboo fiber that is higher causing the bamboo stems are stronger and stiffer and good for soil reinforcement. So one of four types of bamboo above is Gombong bamboo that is most powerful bamboo among the 3 other types of bamboo.

Keywords : Bamboo, bamboo fiber, soil, bamboo characteristics

I. INTRODUCTION

Natural fiber has several advantages over synthetic materials. The advantages of natural fiber include low prices, low density, renewable materials and biodegradable and not harmful to health. Many efforts have been made to explore new natural fibers and the use of plant fibers by different industrial sectors, such as composites for automotive applications and to replace synthetic fibers [1].

Some alternative natural fibers from plants that have been explored including straw fiber, rice straw, grass fibers such as switch grass, Indian grass, napier grass, and bamboo. Some of these fibers have been applied as reinforcing polymer composites [2]. Bamboo is one of the natural fibers that has many advantages. As a construction material, bamboo for structural material has good strength, is easy to implement, economical and environmentally friendly [3]. Bamboo can thrive in Indonesia, bamboo has a period of rapid growth, between 5 cm / hour or about 120cm / day so that bamboo is easily available in Indonesia, the price is cheap and as an environmentally friendly material [4]. Bamboo contains fiber which has many advantages over other natural fibers. The superiority of bamboo, among others, has high parallel fiber strength, has antibacterial properties and bamboo fibers have high tensile strength and small strain. The rough bamboo surface is able to provide a large shear resistance, [4] so that bamboo can be an alternative material in geotextiles because it can replace the geotextile function in retaining soil.

The strength of bamboo is affected by the amount of sklerenkin fiber and cellulose in the bamboo culm. The strength of bamboo on the outside is much higher than the inner bamboo. [5]. The composition of the fibers tends to be more from the bottom up while the parenchyma and its connecting cells decrease. The smaller the size of the fiber, the strength is high.

Bamboo fibers including natural fibers that have cellulose content in fiber, the degree of cellulose polymerization and the angle of fiber microfibrils will affect tensile strength and modulus. Bamboo has a high tensile strength because the substance content in bamboo culms consists of sklerenkin which causes bamboo to have good strength as a building material. Thus bamboo can function as soil reinforcement because of its high tensile strength.

II. RESEARCH METHODS

To find out the type of bamboo that is good as a soil strengthening material, the writer conducted tests on 4 types of bamboo, including Bamboo Duri / Pring Ori (Bambusa Blumeana Spiny or Thorny Bamboo), Bamboo Apus / Bamboo Rope (Gigantochloa Apus / JA & JH Schultes Kurz) , Bambu Gombong / Andong (Gigantochloa Pseudoarundinaceae / steudel Widjaja), Bamboo Temen / Bambu Legi (Gigantochloa Atter). Tests are carried out at Fiber Laboratory Jl. Dayuh Kolot Bandung. As a construction material the use of bamboo for structural material has the advantage of high tensile strength, small strain and has a surface with a high roughness level so that bamboo can be an alternative material in geotextiles because it can replace the geotextile function in soil reinforcement. The rough bamboo surface is able to provide large shear resistance, [4]. To find out which characteristics of bamboo fiber are better, testing is conducted by fiber laboratory testings.

For testing the strength of fiber and bamboo fiber content in this study used the following rules:

- SNI 01-1840-1990 to test fiber length
  The length of the fiber is a number that indicates the length of the fiber in an intact state expressed in millimeters (mm). While the average fiber length is a number showing the average yield of measuring 200 fibers in the same treatment. Then calculate the average fiber length. Measurement of fiber length uses

a monocular microscope. Calculate fiber length with the following formula:

$$A = \frac{\sum X_i f_j}{\sum f_i} \; x \; C$$

Where :

A = The average fiber length is expressed in millimeters

Xi = The value of the measurement of fiber length at observations i is expressed in millimeters

Fi = Frequency value of fiber length measurement on observations to i

C = Factor value on calibration results.

- SNI 0492 - 2008 for the method of Lignin level testing using the Klason Method.
  Lignin is a part of the middle lamella and the cell wall that functions as an adhesive between cells, is an amorphous aromatic compound
- ASTM D1104 - 56 (1978) for methods of test for hollocellulose in wood
  Two grams of extractive free dry sample are weighed and placed in a 250 ml flask with a cover glass cover. Then 150 ml of distilled water was added, 0.2 ml of cold glacial acetic acid and one gram of NaClO2 and placed on a water bath which is maintained a temperature between 70-80 degrees Celsius. Every hour for 5 hours added 0.22 ml. High glacial acetic acid and one gram of NaClO2 then sample is constantly stirred. At the end of five hours, the pumpkin is then placed in ice water until the pumpkin temperature drops to 10 degrees Celsius. The contents of the bottle are filtered with a glass cup that has a coarse porosity that has been known for its weight. The residue is washed to remove CIO2 with 500 mL of distilled water until it changes from yellow to white. The cup is then dried in an oven with a temperature of 103 + _2 degrees Celsius, then cooled in a desiccator, and weighed until the weight is constant. The formula used to determine Holocellulose is as follows:

$$\frac{W_4 - W_3}{100 \; x \; W_2} \; x \; (1000 - W_1)$$

Where :

W1 is the extractive content of alcohol - toluene (percent)

W2 is the extractive sample free dry weight (gram)

W3 is the dry weight of the cup (gram)

W4 is the dry weight of the cup + residue (gram)

- SNI - TAPPI T 203 for testing the levels of alpha, beta and gamma cellulose in pulp

The formula used to calculate the levels of alpha cellulose in bamboo is:

$$\%\, alpha\ selulosa = \frac{berat\ endapan\ kering}{berat\ contoh\ kering} \; x\; 100\ \%$$

III. RESULTS AND DISCUSSION

Based on these methods, the results of laboratory tests state that the type of bamboo that has the best strength between Gombong, Ori, Tali and Temen is Gombong bamboo.

Based on laboratory testings, Gombong bamboo fiber has fiber content, fiber length, inter fiber fibers, namely lignin. The higher bamboo fiber diameter, the bamboo culm will be stronger.

There are 4 types of raw materials used in this study, namely:

1. Bamboo Duri / Pring Ori (Bambusa Blumeana Spiny or Thorny Bamboo)
2. Bambu Apus / Bambu Tali (Gigantochloa Apus / J.A & J.H Schultes Kurz)
3. Bambu Gombong / Andong (Gigantochloa Pseudoarundinaceae / steudel Widjaja)
4. Bamboo Temen / Bambu Legi (Gigantochloa Atter)

Based on laboratory testings, the results of morphological analysis of fiber into the four types of bamboo above stated that:

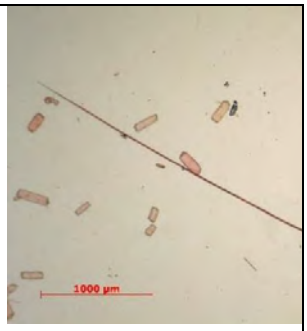
No	Parameter	Unit	Duri/ Ori bamboo	Tali/ Apus bamboo	Gombong /Andong bamboo	Temen /Legi bamboo
1	Fiber Lenght (L), max	mm	5,32	7,80	7,58	8,94
	min	mm	1,20	1,43	1,34	2,00
	Mean	mm	2,76	4,12	3,46	4,24
2	External Diameter (D)	mm	18,71	18,38	23,16	17,08
3.	Diameter internal (I)	mm	6,94	6,43	8,56	7,49
4	Thick Wall (W)		5,89	5,98	7,30	4,79
5	Runkel Number (2W/I)		1,70	1,86	1,71	1,28
6	Slimness (L/D x 1000)		147,29	224,39	149,46	248,44
7	Stiffness (W/D)		0,31	0,33	0,32	0,28
8	Flexibility (I/D)		0,37	0,35	0,37	0,44

	Muhlstep Ratio ($D^2 - I^2D^2$ x 100%)	%	86,26	87,76	86,35	80,76

The characteristics of the four types of bamboo (Duri, Tali, Gombong and Temen) are bamboo which has fibers with an average length of more than 2 mm (2.76 - 4.24), in addition, these 4 types of bamboo have thick walls seen from their Runkel numbers (the ratio between wall thickness and inner diameter) to more than 1, the higher the Runkel number, the thicker the fiber wall. Although the walls are thick but quite slim it can be seen from the slenderness value because of the long fiber, especially on the Tali and Temen bamboo.

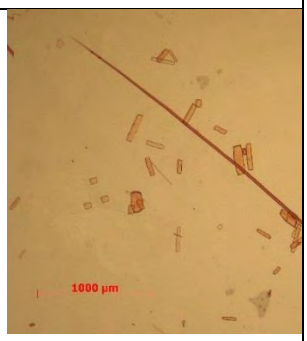
Bambu Gombong has a larger stem diameter and fiber diameter when compared to 3 other types of bamboo as shown in the following figure:

Pic. Fiber Mikroskopik of Temen bamboo



Pic Fiber Mikroskopik of Tali bamboo

Pic. Fiber Mikroskopik of Gombong bamboo



Pic Fiber Mikroskopik of Duri bamboo

From the results of the analysis of the chemical components of 4 types of bamboo, the contents of Lignin, Holocellulose, and alpha cellulose can be seen in the following table:

The results of the analysis of the content of Lignin, Holocellulose and alpha cellulose

No	Parameter	Units	Duri/Ori Bamboo	Tali/Apus Bamboo	Gombong/Wulung Bamboo	Temen/Legi Bamboo
1	Lignin	%	24,97	22,17	24,59	23,30
2	Holoselulosa	%	78,55	76,49	78,81	77,50
3	Selulosa Alpha	%	48,29	48,87	49,51	48,45

Gombong bamboo has the highest chemical components (lignin, holocellulose and selolosa alpha) compared to other bamboos, according to the diameter of the fiber which is thicker than other bamboos. Fiber contains polysaccharides or holocellulose, Lignin, especially in the middle lamella layer, is an adhesive fiber between fibers and is rigid. The higher the lignin content in the bamboo, the more rigid. Holocellulose is a polysaccharide or carbohydrate consisting of cellulose and hemicellulose. Cellulose chains are polymers that are built by glucose monomers alone so that the chain is longitudinal while hemicellulose is a polymer that is built by various monomers, namely manose, glucose, galactose, xylose and arabinose so that the chain is short and branched. Cellulose consists of alpha cellulose, beta and gamma, alpha cellulose namely cellulose which has the longest chain and is resistant to the treatment of 17.5% sodium hydroside solution.

IV. CONCLUSION

Bamboo is an environmentally friendly material so that bamboo fibers include natural fibers which have several advantages over other natural fibers. As a construction material the use of bamboo as a structural material has the advantage of having good strength, easy to implement, economical and environmentally friendly. Bamboo has fiber content and fiber adhesives. Fiber adhesive is called Lignin. As well as fibers that have mechanical properties consisting of fiber content, fiber length, adhesive between fibers, namely lignin and diameter of bamboo fibers which are increasingly high, the bamboo culm is stronger and stiffer, making it is good for soil strengthening. Of the four types of bamboo above Gombong bamboo is the strongest bamboo among the three other types of bamboo.

Based on laboratory testings, Gombong bamboo fiber has fiber content, fiber length, inter fiber fibers, namely lignin and the higher bamboo fiber diameter, the stronger is bamboo culm. Gombong bamboo is a good type of bamboo for soil strengthening.

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