

Development of Biodegradable Board using Water Hyacinth (*Eichornia crassipes*)

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Abstract— The aim of this study was to utilize aquatic weed to become a bio-board with proper mechanical properties. Water hyacinth (*Eichornia crassipes*) is an aquatic weed with a rapid growing rate that usually clogs the irrigation facility and covers the river surface, causing a negative impact to the environment, usually in water environments. In this research, water hyacinth was used to produce bio-boards through cutting, soaking, refining, molding, and drying processes with applied five different loading pressures (2MPa, 3.5MPa, 5MPa, 6.5MPa, 8MPa) in applied 110 degree Celsius. In the producing process of bio-board, hydrogen bond among the cellulose fibers were used instead of used chemical substance and additional additive. Bio-boards were successfully produced under experimental condition. Mechanical properties of each bio-board were investigated. Result of water hyacinth bio-board density was 1.1691 g/cm³, average bending rupture stress 46.21 MPa and tensile rupture stress in average value was 6.64MPa. Bio-board with certain different strength range could be considered to be applied as packaging, seedling pot, mulching or insulating material in advance application.

Keywords— agriculture waste, bio-board, utilization, water hyacinth.

I. INTRODUCTION

About 6 million m³ wood is used for the timber industry, including the production of pulp each year in Indonesia (Ministry of Environment Republic Indonesia, 2012). Wood has many uses in daily life; it is the main cellulose source for housing, furniture, packaging, paper, and other products. In 2007 about 66.2 percent of industrial forest plantation was planted for pulpwood plantation type. During the period 1993-2006, the pulpwood plantation sharply increased from 29,000 ha in 1989 to 200,000 in 2006 with average of 104,000 ha per year (FAO,2009). Those data indicated that wood demand for pulp industry continues to grow in Indonesia, however local forest production have been unable to meet the increasing demand.

Wood based product demand has been increasing nowadays. Wood based product such as, packaging, wall layer, seedling pots and others product which are daily

consume product. The increasing demand for wood based products will impact on increasing the amount of logging, both industrial plantations and forests in general. Intensive use of wood can cause environmental problems such as deforestation, floods, and also global warming.

To overcome these problems, researchers have focused on finding other renewable resources to replace the use of wood for some uses. There is some non-wood which potential resources to be used as pulping material and other wood based product. Intensive use of wood as main cellulose source can be decreased by substituted by other cellulose source material such as biomass.

In this research, water hyacinth (*Eichornia crassipes*) the free-floating aquatic macrophyte growing generally to 0.5 meters that can grow and spread rapidly during rainy season. Water hyacinth is considered as weed (pest) and an unwanted plant. Due to its fast growth and rapid spread, water hyacinth has caused some problem such as the reduction of fish, wide coverage the river surfaces and canals, clogging irrigation facilities and water pollution. Attempts to control or remove the water hyacinth incur high cost and labor and the effect just temporary due to rapid growth.

Based on research conducted by Pasaribu and Swahlita (2007), known that moisture content of fresh water hyacinth is 94.25% with yield of pulp in dry condition of 3.6%. About 1m² of area has 28 kg of fresh water hyacinth, mostly (84%) from those fresh water hyacinth is stem. Water hyacinth is low in lignin content (10%) and contains high amounts of cellulose (60%) and hemicellulose (33%). Water hyacinth currently used as craft and compost (Gunnarson and Petterson ,2007). Recently, bio-board that already developed made from bagasse (sugar cane waste), rice straw, wheat straw and corn straw successfully.

The aims of this research were to utilize water hyacinth to produce bio-board, analyze characteristic of bio-boards from three different biomasses. Physical characteristic such as density, moisture content, bending stress and tensile stress of bio-board were investigated. Producing bio-board with 5 different loading pressures will result in different mechanical properties of bio-boards.

Water hyacinth bio-board produce through a cutting, milling, soaking, refining, soaking pulp and molding

process with applied of five different loading pressures (2 MPa, 3.5MPa, 5MPa, 6.5MPa, and 8MPa) in applied at 110 degree Celsius. Bio-boards were successfully produced under the experimental conditions.

II. MATERIAL AND METHODS

2.1 Bioboard Producing Process

2.1.1 Raw Material Preparation

First, the water hyacinth was dried under sunshine for 3 days (8hours a day). Then, materials were cut (1 cm x 1 cm) then milled with a Toshiba miller to obtain smaller pieces before it was immersed under water for 168 hours.

2.1.2 Refining

After soaking in water for 168 hours, materials became soft due to water absorption into the cells. Materials were refined about 10 minutes with refining machine. The key process in this study was the refining. According to Lumaniaen (2010), refining will give several effects to fibers characteristics such as cutting and shortening of fibers, wall structure, delamination, internal fibrillation/swelling, curling the fiber or straightening the fiber, and redistribution of hemicelluloses from the interior of the fiber to the exterior.

2.1.3 Molding Process

Refined materials were immersed again in water for 7 days to enhance the hydrogen bonding among the cellulose and among the fiber. Furthermore, the materials molded 20 minutes without heat with molding equipment in size 100 mm x 100 mm then molded 60 minutes at 110-degree Celsius. Producing process was showed in Fig 1.

2.1.4 Experimental Condition

In this study water hyacinth was produced with 5 different pressures (2Mpa, 3.5MPa, 5MPa, 6.5MPa, and 8 MPa). The bio-boards were made through 20 minutes without heat molding process, then molded for 60 minutes molding process at 110 °c. In this study the parameters that investigated are bio-board density, bending stress. To determine bio-board's density, first bio-board thickness, dimension and weight was measured. Then, bio-board thickness, dimension, and weight data were calculated into mass (g) and volume (cm³) data.

To investigate moisture content, right after test piece was broken by bending test, test piece was inserted into the test container then dried in oven in applied 105 °c for 24 hours. The test piece was weighed both before and after drying process. Bending test and tensile test were obtained by use of Universal Testing Machine which is connected with sensor and PC to record data automatically during the test. To did bending stress test, 4 specimen tests of each bio-board are prepared at a dimension of specimen test is 50mm x 20mm. 3 specimen

tests from each bioboard were prepared to conduct tensile test.

III. RESULT AND DISCUSSION

Five water hyacinth bio-boards were successfully produced under experimental conditions, shown in Fig.2.

3.1. Density

To determine a bio-board's density, first bio-board's thickness, dimension and weight were measured. Then, bio-board thickness, dimension, and weight data were processed into mass (g) and volume (cm³) data. Finally, using equation (1) bio-board density data was obtained and process into Figure 2.

$$\rho = \frac{m}{v} \quad \text{Equation (1)}$$

Where ρ = density (g/cm³), m = mass (g), V = volume (cm³)
Water hyacinth bio-board densities range 1.057 g/cm³ - 1.279 g/cm³ which are classified as high-density board based on American National Standard for particle board (1999). It reached highest density at 5MPa pressure while the others achieve the highest density by 8MPa pressure. Density of 2MPa and 3.5MPa bio-board showed not significant difference similar with density of 6.5MPa and 8MPa which also not significant difference. Uniformly in fiber size of water hyacinth affect the high density of bio-board. In fact, water hyacinth bio-board were the thinnest board among others, which is explain the tight connection among fibers inside water hyacinth bio-board. Water hyacinth bio-board density shown in Fig.3.

According to American National Standard on Particleboard (1999) High density board define with density above 800 kg/m³ (equal with 0.8 g/cm³). Thus, water hyacinth bio-boards was considered as high-density board.

3.2. Bending stress

Bending strength testing conduct with Universal Testing Machine, (Shimaizu, Japan) connected with load cell sensor device (Kyowa, Japan) and PC to record data during testing. Measurement method set to bending test, calibration between load cell and PC was checked before conduct the test. Specimen was put on the two parts of UTM device and then force applied from upper side until yield point (over the elastic limit of material).

Bending test data was load (N) and the deflection (mm) that was calculated further with i.e (2). However, from Fig .4 it can be seen that the relation between deflections was proportional with the increase of load starting at 0 until approximately 3 mm and then gradually decrease after reach peak load. Since Bio-boards are made from biomass the distribution of the cellulose is not uniformly.

$$\sigma = \frac{3FL}{2bh^2} \quad \text{Equation (2)}$$

Where F is the load (force) at the fracture point (N), L is the length of the support span (mm), b is width (mm), h is thickness (mm).

While the bending test took place, the displacement-load reached its peak at the same time the test piece was broken (permanent damage) and the peak load will represent the maximum load that can be hold by the test piece. Figure below implies at deflection 0 mm to 7 mm the stretching bond happened and when the curve gradually decreases it is implies the material unable to stretch anymore.

Water hyacinth bio-board curve (Fig. 5) show wave pattern when bending strength decrease from 51.75 MPa (2MPa bio-board) to 41.56 MPa (3.5 MPa bio-board) and then increase to 48.12 MPa (5MPa bio-board) slightly decrease to 47.64 MPa (6.5 MPa bio-board) and decrease again until 42 MPa (8MPa). Increasing loading pressure did not have significant effect to bending strength. The best loading pressure to produced high bending strength bio-board with water hyacinth as raw material is 2MPa.

Moisture content analysis for bending and tensile test conducted directly after specimen broken. Water hyacinth bio-board contain of 7 to 9.96 percent moisture content in bending test condition. the moisture content of specimen during the bending test did not give significant impact to the bending strength of material, however the biomass itself that make the different characteristic of material, in this case, bio-board bending strength. This evidence was contrast with Baharoglu *et al* (2012) research result, that state in some level, increasing moisture content was significantly decreased the mechanical strength properties in particleboard case.

3.3. Tensile stress

Tensile strength test was conducted to investigate the maximum force (tensile stress) that bio-board can withstand on before it broke (reach fracture point) and over the elasticity limit..After data recorded data was calculated by follow equation;

$$\tau = \frac{F}{A} \quad \text{Equation (4)}$$

Where ; τ = tensile strength (MPa) , F = force (N), A = section area of specimen (mm²)

Water hyacinth bio-board achieves the highest tensile strength 7.61 MPa by 6.5MPa bio-board and the lowest tensile strength is 5.73MPa by 2MPa bio-board (Fig 6) Water hyacinth tensile strength just obtains 10% of bending strength as shown in Fig 5. Water hyacinth specimen for tensile strength crack without fibrous edge, Moisture content analyses also conduct right after specimen broke. The aim of moisture content analyses on tensile condition is to observe the current condition when the specimen broken due to the tensile stress. In generally, moisture content on tensile condition is higher than

moisture content on bending condition. The range of moisture content on tensile condition is 10.3 percent to 15.5 percent. The result show that tensile strength was lower than bending strength water hyacinth bio-board .

Based on Suboyejo (2004) the resistant of material to deformation strongly depend on the direction of orientation of the load. Since bio-board are made from biomass, which are the cellulose are bounded by hydrogen bound (Van der Wall's force). This is different from metal material that the atoms are bounded by ionic, covalent or metallic bound, which are stronger than hydrogen bounds.

Natural fibers consist of lignin, hemicelluloses, and cellulose. According to Mishra *et al.* (2004) the elementary unit of cellulose macromolecule is anhydro-D-glucose, which contains three alcohol hydroxyls (-OH). These hydroxyls from hydrogen bonds inside the macromolecules itself (intramolecular) and also intermolecular as with hydroxyl groups from the air.

IV. CONCLUSION

Water hyacinth bio-board densities range 1.057 g/cm³ - 1.279 g/cm³ which are classified as high-density board based on American National Standard for particle board (1999). water hyacinth bio board average bending rupture stress, tensile strength respectively were 46.21 MPa,. 6.64 MPa. For further research the effect of fiber length and distribution could be observed to obtain more data.

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Fig 1: Biodegradabel board producing process



Fig 2. Water hyacinth bio-board successfully produce

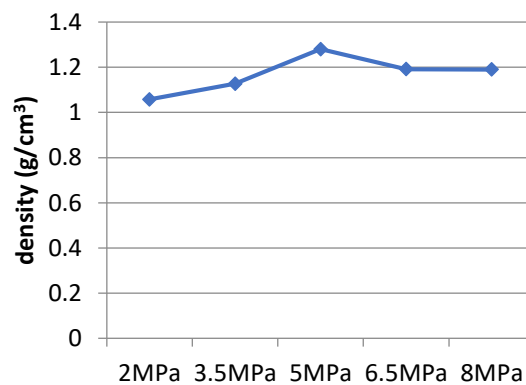


Fig 3. Water hyacinth density

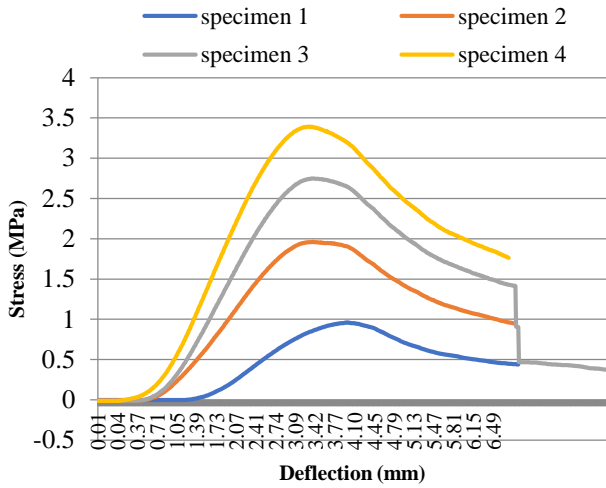


Fig 4. Stress-deflection graph on bending test

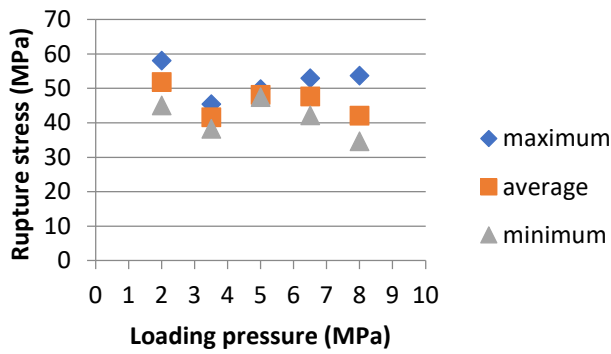


Fig 5. Water hyacinth bio-board rupture bending strength curve

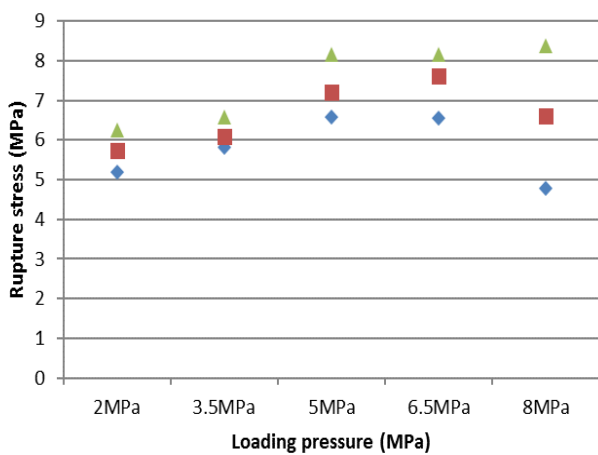


Fig 6. Water hyacinth bio-board tensile strength