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The Analysis Of Micromechanic On Creating Of Gypsum Board Strengthened By Bintaro Fruit Fiber (Cerbera Manghas) With 3d Orientation

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Abstract. This research succeeded in modifying the manufacture of gypsum board with the addition of natural fiber, namely bintaro fruit with the 3D orientation arrangement method. The raw materials for this research are gypsum flour and Bintaro fruit fiber as a matrix and filler. Bintaro fruit fiber previously carried out an alkalization process where the fiber was soaked in a solution of NaOH and distilled water for 24 hours. The manufacture of composites using the ratio of the matrix mass fraction and the filler mass fraction is as follows 100: 0, 99: 1, 98: 2 and 97: 3. The characterizations carried out include density test, moisture content test, flexural strength test and micromechanical analysis. Gypsum board composite based on micromechanical calculations resulted in the highest density value in the control sample, in the best density value was at the filler fraction of 3%, the best moisture content value in the control sample, the flexural strength test value the best of the control sample, but the filler fraction is 3% of the sample with the best fracture resistance. 3D orientation in theory and practice has fulfilled the principle that it is able to increase the physical and mechanical value of gypsum board.

Keywords: *Gypsum, Bintaro fruit, 3D orientation, composite, micromechanical analysis*

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INTRODUCTION

Increasing global concern for environmental sustainability has emerged the greater opportunities for the use of natural fibers as reinforcement or bio-fillers in the manufacture of composites. There are many advantages of using natural fibers to make composite materials such as being made from renewable sources, low price, high specific strength, good bond between fiber and matrix, environmental friendliness, so that it results the superior mechanical-thermal-physical properties of composites. Natural fibers containing lignocellulosic are a good alternative source to replace synthetic fibers in the manufacture of composite materials [1]. One of the natural fibers that has the potential as a biofiller material in the manufacture of gypsum board is bintaro fruit (Cerbera manghas) which has a high content of cellulose, lignin and fiber. On the other hand, bintaro fruit also contains cerberin, especially in the part of the fruit which belongs to the class of saponins, alkaloids, flavonoids and tannins which are toxic and which are used as termite repellents [2].

Gypsum is one of the earliest types of building materials and the history of its application can be traced back 4000 years [3]. Gypsum has a variety of extraordinary advantages, one of which is easy fabrication, low price and energy consumption as well as good aesthetic appearance, good recycling, good fire resistance, good thermal and sound insulation properties, in residential buildings currently gypsum is one of the most important construction materials used. Its application is often preferred over other building materials (plywood, wood etc.) [4]. Gypsum does not have good mechanical properties. This is a limiting factor in the use of gypsum board so that it is necessary to increase the mechanical strength of gypsum. Gypsum has several weaknesses, such as being more brittle, less strong, and less water resistant when it is compared to wood [5].

The occurrence of failure and damage to composites is generally related to the location of the fibers and their binders in the material [6]. The 3D orientation of the composite results in higher damage tolerance and resistance to delamination [7], as well as sealing of damage between the matrix and filler in the composite [8]. Making gypsum board by adding natural fibers with a 3D orientation where the fibers will be arranged from 3 different directions will affect the increase in compressive strength, tensile resistance, and elastic modulus of gypsum board [1]. According to Muntangkaw (2021) the best fiber orientation efficiency (K) parameter is 3D with a value of K = 1/5 when compared to 1D K = 1 and 2D K = 3/8.

This study aims to examine the mechanical and physical properties of bintaro fiber reinforced gypsum composites. The 3D orientation method is used to arrange bintaro fibers in a gypsum matrix as described by Muntongkaw (2021). The mass fraction of bintaro filler to gypsum will be varied to determine the mass fraction that gives the best mechanical properties. The reference for the mechanical and physical properties of gypsum composites in this study used SNI 03-6384-2000 regarding gypsum board.

RESEARCH METHOD

Research Tool and Material

The tools used in this study were knives, aluminum molds measuring 40 cm x 20 cm x 2.5 cm, glass as covering the molds 40 cm x 20 cm x 2 mm, mixing containers, spatulas, scissors, beakers, digital balances, calipers. shovel, screw micrometer, scroll saw model RSSS 125, electric oven and sacks. The materials used in this study were bintaro fruit (Cerbera Manghas), gypsum flour, sodium hydroxide (NaOH), distilled water and water.

Preparation of Bintaro fiber

Bintaro fruit is separated between the fiber and the seeds, the fiber that has been separated is then dried in the sun for 5 days. The dried fibers were cut into lengths of 6 cm. The fibers were alkalized with NaOH solution and distilled water while the concentration of the solution was 5% by weight of the distilled water for 2 hours to remove the lignin content in the Bintaro fruit fiber [9]. The fiber that has been alkalized is then dried in the sun for 8 hours.

The Production of Gypsum Board

Gypsum board was created through a mixture of gypsum flour and bintaro fruit fiber with a ratio of matrix mass fraction and filler mass fraction of 100 : 0, 99 : 1, 98 : 2 and 97 : 3 for a clearer comparison of the gypsum board composition levels can be seen in Table 1. Mixture Gypsum flour is the matrix for making this gypsum board and Bintaro fruit fiber is a filler in this study. The gypsum mixture is made from gypsum flour and water in a ratio of 3: 1 which is stirred using a spatula until it is homogeneous. Preparation of control gypsum samples was made by mixing gypsum flour and water with the comparison in Table 1 which was stirred using a spatula until homogeneous and then poured into a mold and the sample was covered with glass so that the surface of the sample was smooth and flat. This process can be seen more clearly in Figure 1. Preparation gypsum sample 1, gypsum sample 2, gypsum sample 3, made with a mixture of gypsum flour and bintaro fruit fiber. The gypsum mixture is divided into two parts, namely the first coating and the second coating. The first layer is put into the mold first, then the fibers that have been mass calculated and arranged in 3D orientation are put into the mold, then coated with the second layer and then covered with glass so that the sample surface is smooth and flat. The sample was allowed to stand for 5 hours and then removed from the mould. To make this process clearer, it can be seen in Figure 2. Furthermore, the samples were allowed to stand at room temperature for 28 days before cutting the samples.

Table 1. Comparison of gypsum board composition

Sample Code	Extract of bintaro fruit (%) + gypsum flour (%)	Mass of bintaro fruit extract (gram)	Mass of gypsum flour + water (3:1)	Composite of total gipsum (gram)
Control*	0 : 100	0	1575 525	2100
Sampll 1†	1 : 99	21 : 3	1559 520	2100
Sampll 2	2 : 98	42 : 3	1544 515	2100
Sampll 3	3 : 97	62 : 3	1527 509	2100

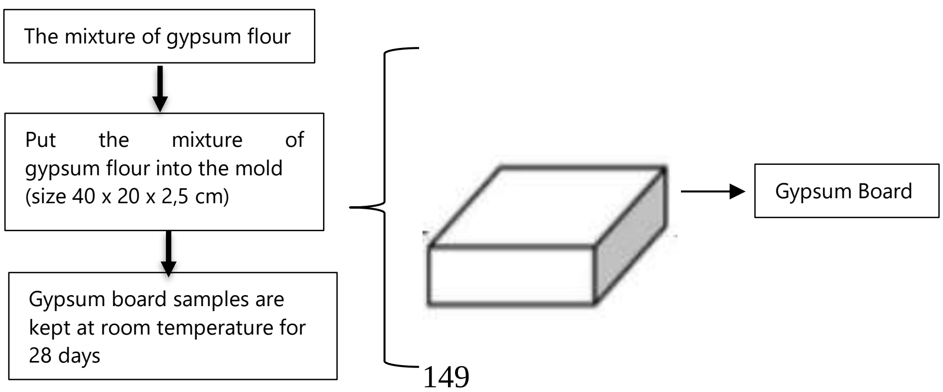

Figure 1. The Production of control gypsum board samples

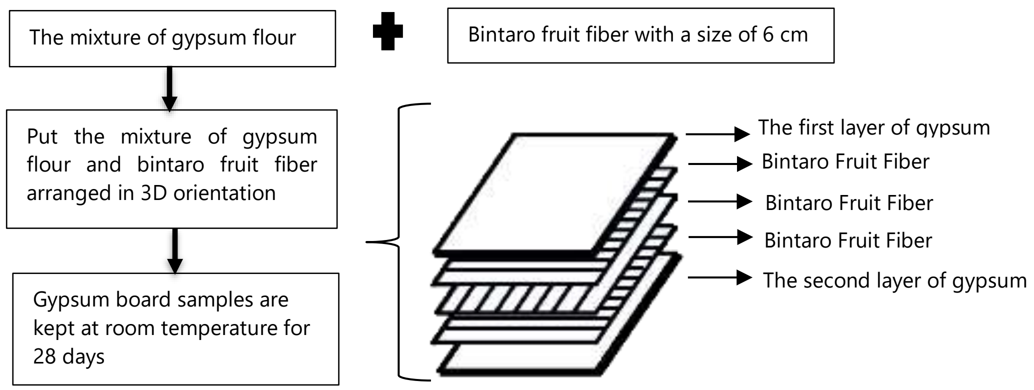

Figure 2. The Production of Gypsum Board with 3D orientation

Testing Process

Micromechanical Analysis

Micromechanical analysis shows that the relationship between the physical and mechanical properties possessed by the matrix and fibers and the composites which they form. Fiber and matrix are considered as separate elements that bind each other which is a separate composite property [10].

Filler Density and Matrix

Calculation of Filler Density and Matrix can be seen in Equation (1).

$$\rho_f = \frac{m_f}{v_f} \quad ; \quad \rho_m = \frac{m_m}{v_m} \tag{1}$$

Description: ρ_f = Mass of filler; m_f = Mass of filler; v_f = volume filler; ρ_m = Mass of matrix ; m_m= Mass of matrix ; v_m = Volume matrix

Mass fraction

The mass fraction of the composite consists of the mass fraction of the filler and the matrix. The calculation of the mass fraction can be seen in equation (2) [11].

$$M_f = m_f \; m_c \; ; M_m = m_m \; m_c \tag{2}$$

Description: M_f ==Mass fraction of filler ; m_f = Filler mass ; m_c = Composite mass ; M_m= Mass fraction matrix ; m_m = matrix mass ; m_c = Mass configuration

Fractional volume

Composite volume consists of filler volume ($\boldsymbol{v_f}$) and matrix volume ($\boldsymbol{v_m}$). The filler and matrix volume fractions are defined in equation (3).

$$V_f = v_f \; v_c ; V_m = v_m v_c \tag{3}$$

Description: V_f = volume fraction of filler; v_f = Volume of filler; v_c = Composite volume; V_m = volume of fraction matrix; v_m= Volume matrix; v_c = Composite volume

The Relationship between mass fraction and volume fraction

Relationship between $m_c = \rho_c v_c$; $m_f = \rho_f v_f$; $m_m = \rho_m v_m$ s thus it can be concluded according to Equations (4) [12] and (5).

$$V_f = \frac{(\frac{m_f}{\rho_f})}{\left(\frac{m_f}{\rho_f}\right)+\frac{m_m}{\rho m}} \quad (4)$$

$$V_m + V_f = 1 \quad (5)$$

Description: V_f= volume of filler fraction ; m_f = Mass of filler; ρ_f= Mass of filler; V_m = mass volume fraction ; V_m = Mass of volume fraction ; ; p_m= Mass of matrix

Composite Mass

Composite mass can be asserted in terms of mass fraction and volume fraction. In the form of volume fractions can be seen in Equation (6) [13] :

$$\rho_c = \rho_f V_f + \rho_m V_f \quad (6)$$

Description: ρ_c = Mass of the composite; ρ_f = Mass of filler; ρ_m = Mass of matrix ; V_f = volume of filler fraction

Gypsum Board Composite Testing

Composite tests to be carried out include density testing, moisture content testing and flexural strength testing.

Density Test

Density is a measure of the compactness of a particle in a volume. In this study, the density tested was filler, matrix and composite. This test is carried out to see the density: filler, matrix and composite. The size of the density test object made is (10 x 10) cm in accordance with SNI 03-6384-2000. Density calculation can be seen in Equation (7).

$$\rho = \frac{m}{V} \quad (7)$$

Information : ρ = Density of composite $\frac{g}{cm^{3)}}$) ; m = Composite mass (g) ; V = (cm^3)

Water Content Test

The moisture content of the composite board is calculated based on the initial weight (Ba) and oven dry weight (Bk). Gypsum board moisture content is calculated based on SNI 03-6384-2000. Calculation of water content can be seen in Equation (8) :

Water Level (%) = [(Ba-Bk)/Bk] x 100% (8)

Note: Ba = initial weight of the test sample (g) ; Bk = oven dry weight of the test sample after drying (g)

Flexural Strength Test

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Flexural strength test is the ability of a material to withstand bending forces in a direction perpendicular to the cross section until the test sample fractures. The flexural strength value of gypsum board is determined using Equation (9) based on ASTM C 473.

$$KLMN = \frac{S^3 \Delta B}{4lt^2\ \Delta D}\ X\ 100 \tag{9}$$

Description: : $KLMN$ = Flexural toughness modulus of elasticity (kgf/cm2) ; S = length of stretch (cm) ; l = Width of fiberboard test sample (cm) ; t = Thickness of the fiberboard test sample serat (cm) ; ΔB = Difference in load (B1- B2) taken from the curve (kgf) ; ΔD = Deflection (cm) that occurs at the difference in load (B1 – B2)

FINDING AND DISCUSSION

The Calculation of Composite Density in accordance with Micromechanical Theory

The results of the micromechanical analysis of the gypsum board sample reinforced by Bintaro fiber with a 3D orientation can be seen more clearly in Figure 3 (a). The highest composite density micromechanical analysis value was found in the control sample without filler mass fraction, while in sample 2 with 1% filler mass fraction and sample 3 with 2% filler mass fraction decreased, sample 4 with 3% filler mass fraction the density value increased again .

Micromechanical analysis of composite density resulted from the calculation of matrix volume fraction, filler volume fraction, matrix density and filler density used in this study. In the control sample without the addition of filler mass fraction the resulting composite density value is 1.67 (g/cm3), the addition of 1% filler mass fraction the composite density value is 0.4 (g/cm3), the addition of 2% filler mass fraction the composite density value is 0.48 (g/cm^3) and the addition of a filler mass fraction of 3% composite density value is 1.53 (g/cm^3). The higher the filler volume of the composite, the greater the composite density value. The results of micromechanical analysis show that the addition of filler with a 3D orientation can increase the density of the composite, at 3% filler mass fraction the value of composite density increases by 2% and 2.1% when it is compared to 1% and 2% filler mass fractions. However, the volume of filler used was not large enough so that the density of the composite in the mass fraction of 1%, 2% and 3% was not higher than the density of the composite in the control sample.

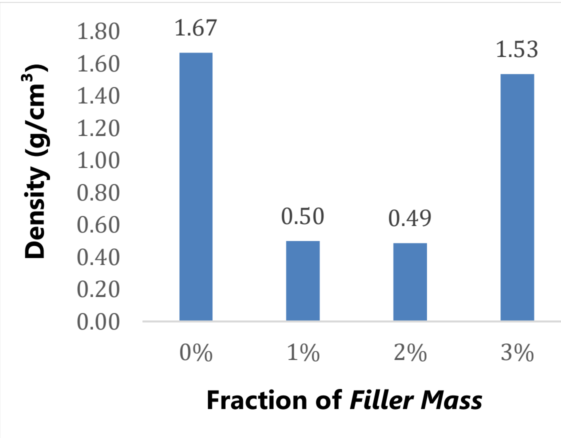
The Test Result of Composite Density

The results of testing the density of the gypsum board samples reinforced by bintaro fiber with a 3D orientation for more details can be seen in Figure 3 (b). This value is the measurement value for each fraction which is carried out in triplicate (three times). The gypsum board density value decreased from the control sample to the sample with a filler mass fraction of 1%, 2% and increased in the sample with a filler mass fraction of 3%.

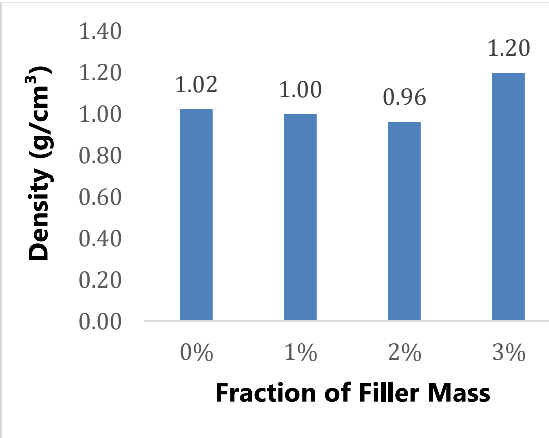
The results of the density of the gypsum board composite in the control sample obtained a value of 1.02 (g/cm^3), the addition of a 3% filler mass fraction the composite density was 1.20 (g/cm^3), the 2% filler mass fraction the composite density value was 0.96 (g/cm^3) and the filler mass fraction 1% composite density value of 1.00 (g/cm^3). The composite density values for the 3% filler mass fraction increased by 0.25%, 0.20% and 0.17% from the 1%, 2% filler mass fraction and control samples. The density value of the 3% filler mass fraction is much greater when compared to the 1%, 2% filler mass fraction density value and the control sample, the composite height in the 3% filler mass fraction is smaller when compared to the 1%, 2% and 1% filler mass fraction. control sample. This is due to the 3% filler mass fraction of the composite matrix entering the filler cavity, so that the resulting volume is smaller.

Micromechanical Analysis

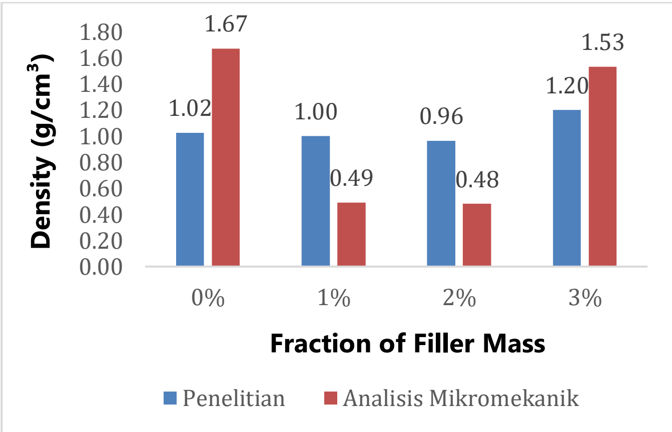
The comparison of the results of micromechanical theory and practice can be seen in Figure 3 (c). The results of micromechanical theory and direct practice tend to have in common, namely the highest density value with the control sample, samples with 1% and 2% filler mass fractions the density value tends to decrease and the 3% filler mass fraction of density value increases again.



(a)



(b)



(c)

Figure 3. (a) Density Testing Results Based on Micromechanical Theory, (b) Practical Density Testing Results, and (c) Density Test Combined Results Based on Micromechanical Theory and Practice

The results of micromechanical theory and practice have the same trend, the highest density value is found in the control sample in micromechanical theory, while in direct practice the highest density value is in the 3% filler mass fraction, samples with 1% and 2% filler mass fractions experience a decrease in density values, samples with a filler mass fraction of 3% the density value increased again. Samples with a filler mass fraction of 1% and 2% in practice decreased, this was due to the presence of voids or cavities. Voids are a type of defects that appear in composite materials due to the loss of some elements during the fabrication process. The presence of voids can affect the mechanical properties and increase the potential for composite damage [14]. The difference in results from micromechanical theory and practice is due to one of the factors that there are cavities that are not calculated in the micromechanical density calculation.

The Test Result of Water Content

Water content is the amount of water contained in a composite [15]. The water content is highly dependent on the surrounding air conditions. The results of testing the water content of the gypsum board sample reinforced by Bintaro fruit fiber with a 3D orientation for more clarity can be seen in Figure 4.

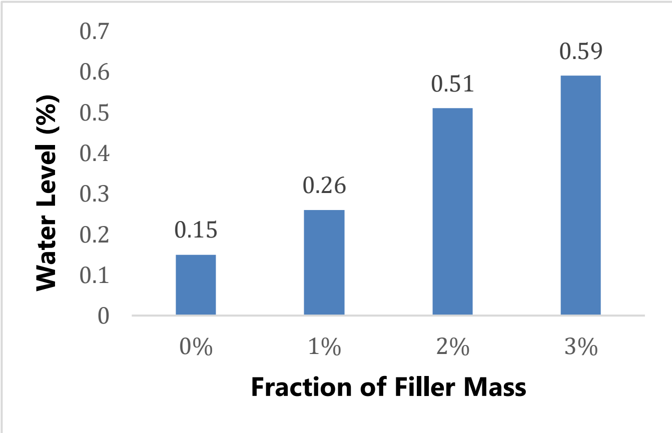


Figure 4. Gypsum Board Water Content Test Results

Dealing with Figure 4, it can be seen that the water content value of gypsum board has increased, the more bintaro fruit filler used, the higher the water content value. This is due to the higher ratio of bintaro fruit filler, besides that the higher gypsum matrix fraction can fill the space between the bintaro fruit fillers. In this study the lowest levels were in the control sample. The more matrix used, the lower the water content, this is because the bonds between the matrices will be tighter so that water will be difficult to enter between the matrices. The water content tends to be higher in the filler mass fraction of 1%, 2% and 3%. The use of more and more matrix can cause fewer cavities in the composite filled with water because these cavities have been filled with matrix that has frozen [16].

The Test Result of Flexural Strength

The flexural strength test of gypsum board was carried out using the UTM (Universal Testing Machine) tool. The principle of flexural strength testing is that the sample is given a force, when the sample breaks, the flexural strength value is recorded on the testing computer. The results of the flexural strength test of the gypsum board sample can be seen more clearly in Figure 5.

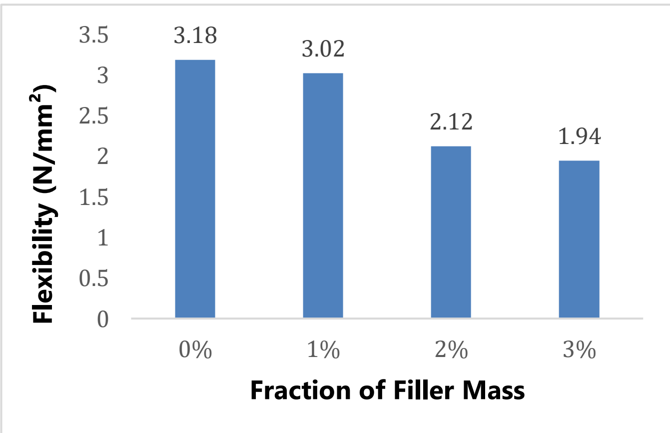


Figure 5. Results of the Flexural Strength Test of Gypsum Board

Regarding to Figure 5, it can be seen that the control sample with the highest flexural strength value while the gypsum sample with a filler mass fraction of 1%, 2% and 3% has decreased. decrease in flexural strength. This is due to the sample with a filler mass fraction of 1%, 2% and 3% using less matrix when compared to the control sample. Referring to Figure 2, the force exerted on the composite is the same, but the amount of matrix in the first layer is much less according to the mass fraction of the matrix used. In the test after the compressive force was transferred to the fiber in the 3% filler mass fraction, the fiber was able to survive stronger than the 1% and 2% filler fractions. It was concluded that the mass fraction of 3% filler, the fracture time from the first layer to the fiber was faster, but the fracture time to the second layer was longer, the mass fraction of the 1% and 2% filler was also the same. When the control sample is given a compressive force, will break completely due to there are no fibers binding the matrix.

CONCLUSION

The finding of micromechanical analysis research on the manufacture of gypsum boards reinforced by bintaro fiber with a 3D orientation, it can be concluded that:

1. In theory and practice, 3D orientation fulfilled the principle that 3D orientation could increase the physical and mechanical value of gypsum board.
2. In the micromechanical analysis, the density and flexural strength have increased in line with the increase in the filler fraction. However, in this study, the amount of filler fraction added was still insufficient due to the value of the filler fraction was a constant which affected the value based on the micromechanical analysis formula.

SUGGESTION

The results of micromechanical analysis research on the manufacture of gypsum board can be suggested as follows:

1. Dealing with the calculation, it indicates that the micromechanical value will increase if the used amount of filler fraction increases.
2. The 3D orientation arrangement must be updated, the fiber arrangement used can be alternated with gypsum flour.

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