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The Effect of Bamboo Species and Particle Geometry on Physical Properties of Cement Board

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Abstract:
Non-wood raw materials that are lignocellulosic include bamboo, it mostly found in the tropics area such as Asia, Africa and America. The potential of bamboo in Maluku especially Seram Island is spread among others in Taniwel located in Buria village, and Kairatu sub district, where there are several types of bamboo such as bamboo petung (Dendrocalamus asper), bamboo jawa (Gigatocchloa atter) and bamboo suanggi (Bambussavertillata) can be used as raw material of cement board. The cement board as well as the particle board, the particle shape for the cement board, among others, can be a flake, shaving, strand, splinter, wood wool (excelsior), fiberand wood flour. This study used three species of bamboo as a factor A and particle geometry as factor B with each of them three levels and three replications, where the experimental design used was a completely randomized design. The result of the analysis showed that the particle geometry had a significant effect on the oven dry moisture content and had a height significant effect on air dry density and oven dry density. The data show that the average air dry moisture content rate is 4,544%, oven dry of 8.482%, air dry density of 0.542 g / cm3, oven dry density of 0.547 g / cm3, water absorption of 21.15% and thickness swelling of 25.45 %.

Keywords: *bamboo species, particle geometry, physical properties of cement board*

1. Introduction

Wood industry is an important forestry industry in the utilization of forest resources, but the serious problem faced by the wood industry today is the shortage of wood raw materials (Sulastiningsih, 2008). To overcome these problems, various policies have been undertaken by the government, among others, by developing industrial forests and community forests. In addition, wood processing activities should be done as efficiently as possible and the resulting product is resistant to the attack of wood destructive organisms and flame retardants, where the cement board is a wood product that has such properties.

The cement board is one of wood composite products made of mixed wood particles or other lignocellulosic materials with cement as adhesive material (Haygreen and Bowyer, 1982; Sulastiningsih, (2008), Sibarani, 2011; Simbolon, *et al.*2015). The commonly used adhesive is Portland cement because it is easy to obtain and provides a good enough strength.

Non-wood raw materials that are lignocellulose include bamboo, mostly found in tropical areas such as Asia, Africa and America (Manuhua, 2005). The potential of bamboo in Maluku, among others, in Seram Island is in Taniwel, especially in the village of Buria with an area of 650 ha, in Kairatu sub-district spread in several places, namely Seriholo, Tala, Sumeit, Pasinaro, Ahiolo-Abia, Watui, Hukukecil, Rumakai, Latua, and Hualoi. There are various types of bamboo, among others: bamboo petung (*Dendrocalamus asper*), bamboo jawa (*Gigatocchloa atter*) and bamboo suanggi (*Bambussavertillata*), theycan be used for various purposes, among others, as raw material for cement board making.

The cement board, as well as the particle board, forms particles for cement boards such as flakes, shavings, strands, splinters, wood wol, fiber and wood flour (Aro, 2004; Sulastiningsih, 2008; and Khonsari, *et al.* 2015). Cement board has better properties than particle board that is more resistant to fungus, waterproof and fireproof (Maloney, 1977), and also more resistant to ground termite attack when compared with the raw material of wood (Sukartana, *et al.*2000). Violet. (2012). adding that cement board has several advantages such as not demanding high raw material requirements, easy to obtain cement on the market, non-emitting products such as particle board with organic adhesive (Urea formaldehyde) and the manufacturing process is relatively easy.

On the other hand, some researchers have investigated in depth the addition of chemicals in wood, cement and water mixtures to increase cement hardening (Sulastiningsih, 2008). Chemicals such as calcium chloride (CaCl2), ferric chloride (FeCl3), ferrous sulfate (Fe2(SO4)3), magnesium chloride (MgCl2), and calcium hydroxide (Ca(OH)2) have been reported to reduce hardening of cement and wood (Moslemi *et al*., 1983). Paul. (2017). suggests that studies have shown that the addition of two percent of calcium chloride (CaCl2) has the same hardening strength at 50^0F as an ordinary concrete at 70^0F. Regardless of the type of temperature or cement type, concrete mixtures containing calcium chloride will always have a faster hardening rate than regular concrete. The beneficial effects of calcium chloride will be more pronounced at lower temperatures. The rate of effect of accelerated hardening measured at the time of final concrete preparation can be reduced by two thirds if two percent of calcium chloride is added.
Based on the problems are stated above, the purpose of this study is to examine the effect of bamboo species and particle geometry on the physical properties of cement board

2. Materials and Methods

2.1. Material
The materials used in this research are three species of bamboo namely bamboo petung and bamboo java taken from the village of Liliboi and bamboo suanggi taken from the village Rumahtiga, and three kinds of particle geometry namely flours, shavings, mixture of flours and shavings, Portland cement as adhesive, water and lime (CaCl2) as catalysts

2.2. Method

2.2.1. Particle Manufacture and Cement Board Making
The stages in particle and cement board making are:

a. Bamboo that has been cleaned skin, then split, and then shaved to get flours and shavings.
b. The shavings and flours are weighed respectively at 5 g, dried in the oven until the severity is constant.
c. Weighing the sample of each experimental unit, whether flours, shavings and the mixture of flours and shavings.
d. Each experimental unit was immersed in water and given 2% CaCl2 solution for 15 minutes, and mixed with cement, with cement ratio: raw material: water was 3: 1: 1.
e. After that is made MAT (temporary mold), and pressed for 15 minutes.
f. Furthermore, the MAT is naturally cool press to the thickness of the desired thickness.
g. After the cold press then the product is conditioned for two weeks.
h. After that the finished cement board is made sample test

2.2.2. Test Sample Preparation of Cement Board
The cement board is made in the laboratory of Forest Product Technology Department of forestry, Agriculture
Faculty, Pattimura University and SMK Negeri Ambon, measuring 31 x 25 x thick (±3cm) and made sample test with size according to ASTM D 1037 (Book of ATM Standard, 1981; and Shawia, *et al*. 2014) where:
Sample for moisture content and density measuring 5 x 5 x thick (cm), test samples for water absorption and thickness swelling of 15x12.5x thick (cm)

2.2.3. Testing the Physical Properties of the Cement Board.
The physical properties are calculated based on the formula put forward by Brown *at al*. (1952), Skaar (1972), Bodig and Jayne (1982), Saputra, (2014), Simbolon, *et al*. (2015) and Khonsari, *et al*. (2015) as follows

1). Moisture Content and Density
Moisture content can be calculated as follows

$$Moisture\ content\ (\%) = \frac{Wa-Wo}{Wo} x100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:
Wa = the weight of the test sample under certain moisture content conditions (grams)
Wo = oven dry weight (gram)

The density of the cement board can be calculated by the formula:

$$\rho = \frac{Wo}{V} g/cm^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where:
$\rho\ = Density\ (\frac{g}{cm3})$
W0 = Oven dry weight (g)
V= sample test volume ((cm^3)

2). Water absorption

The initial weighing is to determine the initial weight of the test sample and subsequently soaking for 12 hours, then discharged and dried for 10 minutes and weighs the weight. Water absorption can be calculated by the formula:

$$Water\ absorption\ (\%) = \frac{Wa - Wi}{Wi} x100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where:

Wi = initial weight (g)

Wa = weight after immersion (g)

3). Thickness Swelling

The test sample was immersed for 12 hours, after which it was removed and conditioned for a further 10 minutes before it is measured. The thickness swelling testing is performed by measuring the initial thickness of the test sample on all four sides, and the final thickness after immersion on all four sides. Thickness swelling can be calculated by the formula:

$$Thickness\ swelling\ (\%) = \frac{T2 - T1}{T1} x100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where:

T1 = thickness before immersion (cm)

T2 = thickness after immersion (cm)

2.2. 4. Data Analysis

Physical properties were then analyzed using a completely randomized design the first factor was bamboo species as a factor A consisting of three levels (a1 = bamboo petung, a2 = bamboo jawa and a3 = bamboo suanggi), the second factor was the particle geometry as a factor B consisting of three levels (b1 = flours, b2 = shavings, b3 = flours and shavings combination), and three replications, with themathematical models according to Steel and Torrie, (1981) as follows:

$Yijk = \mu + \alpha i + \beta j + \alpha i\beta j + \varepsilon ijk$.. ….. (5)

Where:

Yijk = response (moisture content, density, water absorption and thickness swelling

μ= general mean

αi = effect of bamboo sp (factor A).

βj = effect of geometry particle (factor B).

$\alpha i\beta j$ = interaction effect of bamboo sp and particle geometry (AB)

ϵijk= the effect of the experiment error

If factor A, B and interaction AB show a significant effect on respos measured then proceed with Tukey pairwise comparisons (Steel and Torrie, 1981) with the formula:

W = qα (p,fe) Sy ……………………………………………………………………(6)

Where:

W = Critical value

qα = obtained from Table A. 8

p = the number of treatment

fe = error df

$Sy = \sqrt{MS/r}$

2.2.5. Processing data using Minitab 17software.

3. Results and Discussion

3.1. Results

The analysis of variance the effect of bamboo sp, particle geometry and their interaction on the physical properties of cement boards are based on Appendix. 2 is presented in Table 1.

Physical properties	Effect of Bamboo sp (A)	Effect of Particle Geometry(B)	Interaction effect of AB
Air dry moisture content	ns	Ns	ns
Oven dry MC	ns	*	ns
Air dry density	ns	**	ns
Oven dry density	ns	**	ns
Water absorption	ns	Ns	ns
Thickness swelling	ns	Ns	ns

Table 1: Recap Analysis of variance the Effects of Bamboo sp, particle geometry and their interactions on Physical Properties of the Cement Board

Where:
* = significant effect
** = height significant effect
ns = no real effect

Table 1 shows that particle geometry gives significant effect on oven dry moisture content and it gives height significant on air dry density and oven dry density, thus continued with Tukey Pairwise Comparisons. as follows:

3.1.1. The Effect of Particle Geometry on Oven Dry Moisture Content

- Grouping Information Using the Tukey Method and 95% Confidence

Particles	N	Mean	Grouping
Flour (b1)	9	9.69333	A
Mix. b1+b2 (b3)	9	8.37333	A B
Shaving (b2)	9	7.37889	B

Table 2: Tukey Pairwise Comparisons: Response = air dry MC, Term = particle geometry
Means that do not share a letter are significantly different.

3.1.2. The Effect of Particle Geometry on Air Dry Density

- Grouping Information Using the Tukey Method and 95% Confidence

Particles	N	Mean	Grouping
Flours (b1)	9	0.702222	A
Mix. b1+b2 (b3)	9	0.467778	B
Shavings (b2)	9	0.456667	B

Table 3: Tukey Pairwise Comparisons: Response = Air dry density, Term = particle geometry
Means that do not share a letter are significantly different.

3.1.3. The Effect of Particle Geometry on Oven Dry Density

- Grouping Information Using the Tukey Method and 95% Confidence

Particles	N	Mean	Grouping
Flours (b1)	9	0.700000	A
Mix. b1+b2 (b3)	9	0.476667	B
Shavings (b2)	9	0.464444	B

Table 4: Tukey Pairwise Comparisons: Response = Oven dry density, Term = particle geometry
Means that do not share a letter are significantly different.

3.2. Discussion

3.2.1. The Effect of Bamboo SP on the Physical Properties of Cement Boards

1). Moisture Content
The value of air dry moisture content of cement board (App. 1.1) ranged from 2.55 - 9.59% and on oven dry conditions (App. 1.2) ranged from 4.4 - 12.73%, with the average value of 4.544% and 8.482%,
Research data also shows that the lowest moisture content of bamboo java (a2) and largest in bamboo suanggi (a3), but the analysis of variance(Table 1) indicates that the bamboo spdoes not give significant effect on air dry moisture content and oven dry moisture content, so it does not continue with pair wise comparisons.
The results of this study are inconsistent with Bin Na, *et al*. (2014), which states that different wood species can produce different moisture content. This results are not different from International Standard (Anonymous, 1987), because the average moisture content value is less than 12%

2). Density
The average air dry density of the cement board (App. 1.3) ranges from 0.37 to 0.87 g / cm^3 with an average value of 0.542 g / cm^3, whereas the oven dry density of cement board (App. 1.4) ranges from 0.4 to 0.87 g / cm^3 with an average value of 0.547 g/ cm^3.The research data also shows that the highest density on bamboo suanggi (a3) and the lowest on bamboo java (a2). The analysis of variance (Table 1)shows that the bamboo spdoes not give significant effect on the cement board density either the air-dry density and the oven dry density, so they do not continue with pair wise comparisons.

These results differ from those of Bin Na, *et al*. (2014) which suggests that different types of wood species will affect the compatibility of cement wood, it will affect the difference in cement board density.

3). Water absorption

The value of water absorption of cement boards (App. 1.5) ranges from 6.67 - 32.41% with an average of 21.15%, where the smallest water absorption occurs in bamboo suanggi (a3) and the highest in bamboo petung (a1).

Bin Na, et al. (2014) suggests that different types of raw materials will affect the compatibility of cement wood, it will affect the different absorption properties of the products, but the analysis of variance (Table 1) shows that the bamboosp does not give significant effect on the water absorption properties of the cement board.

4). Thickness swelling

The value of the thickness swelling of the cement board (App. 1.6)ranges from 13.31 - 37.28% with an average of 25.45%, where the smallest thickness swelling occurs in bamboo jawa (a2) and the highest in bamboo suanggi (a3), but the analysis of variance (Table 1) shows that bamboo species does not give significant effect on the thickness swelling of the cement board, then it is not followed by Tukey pairwise comparisons test. Bin Na, et al. (2014) suggests that different types of raw materials will affect the compatibility of cement wood, it will have an impact on differences in the thickness swelling of the resulting product.

The results of this study differ from those of Fernandez and Taja-on (2000) where the thickness swelling of cement board of rice straw is 5.58%, while Sutigno *et.al*. (1977) shows that the thickness swelling of cement board of Kenanga wood (*Cananga odorata*) amounted to 4.89% and Olorunnisola. (2001). were range of I.1 to 8.6% of rattan.

This difference occurs because the cement board density produced in this study is low (0.37 g / cm3 - 0.87 g / cm3), so it is assumed that the bond between wood particles with cement is less compact or less strong and the cement board produced is less dense. In addition, the cement content and the pressures used in this study are different from previous studies to be the cause of differences in the nature of the resulting cement board

<u>3.2.2. The Effect of Particle Geometry on the Physical Properties of Cement Boards</u>

1). Moisture content.

The Tukey pairwise comparisons (Table 2) shows that the highest oven dry moisture content in flour (b1) is 9.69% and significant difference to mixture particles (b3) and shaving (b2), where the lowest in shaving (b2) is 7.38%. The results of this study are accordance with the opinion of Simbolon, *et al.* (2015) which revealed that the larger the particle size (30 mesh) the lower the moisture content. This is occurred because the larger the particles the more the amount of cement that covers the surface of the particle, whereas the smaller particles, with the same amount of cement cannot cover all the surface of the particles.

2). Density

The data in Table 1 show that factor B (particle geometry) gives height significant effect on air dry density and oven dry density of cement board, so they continue with Tukey pairwise comparisons. The Tukey pairwise comparisons in Tables 3 and 4 indicate that the highest average density are both air dry and oven dry density of cement board by using flours geometry (b1) and significant difference to others, while lowest for shavings geometry (b2).

This result is different from the opinion of Simbolon, *et al*. (2015), which suggests that cement boards made of finer particles (80 mesh) are lower density than cement boards made of large particles (30 mesh)

3). Water absorption

Analysis of variance (Table 1) shows that particle geometry does not give significant effect on water absorption. so, it is not followed by Tukey pairwise comparisons. The experiment data (6.67-32.41%) are below the data of Olorunnisola. (2001). which stated that the ranges of values water absorption were 30.8 to 51.3% for water absorption,

4). Thickness swelling.

The value of the thickness swelling of the cement board (Appendix 1.6) ranged from 13.31 to 37.28% with an average of 25.45%, where the largest thickness swelling occurred on cement board using flour particle (b1) that is aqual to 27.36%. Table 1 shows that particle geometry (B) does not give significant effect on thickness swelling of the cement board, so it is not followed by Tukey pairwise comparisons. The results of this study differ from those of Fernandez and Taja-on (2000) who found that the thickness swelling of cement board from rice straw was only 5.58%; Sutigno *et al.* (1977) only 4.89% of Kananga wood (*Cananga odorata)* and Olorunnisola. (2001). were range of I.1 to 8.6% of Rattan. This difference is thought to be due to differences in raw materials, the amount of cement, type and the number of catalyst and the size of pressure are used to produce different density of cement boards, which directly affects the differences of thickness swelling of cement board. Simbolon, *et al*. (2015) suggests that thickness swelling is a physical property that determines the use of a cement board for exterior or interior purposes. Based on this opinion, the cement board produced in this study is used for interion purposes

3.2.3. The Effect of Interaction between Bamboo Sp and Particle Geometry on the Physical Properties of Cement Boards

The analysis of variance (Table 1) shows that the effect of interaction between bamboo sp and particle geometry does not give significant effect on the physical properties of the cement, so they do not continue with pairwise comparisons.

4. Conclusions

The analysis of variance showed that particle geometry (factor B) gives significant effect on the oven dry moisture content, and it gives height significant effect on air dry density and oven dry density of cement board.

The results of Tukey pairwise comparisons show that: the cement board produced from flours geometry (b1) has the highest oven dry moisture content and is significantly different from the cement board produced from shavings (b2); the cement board produced from flours geometry (b1) has the highe stair-dry density and oven dry density and it is significantly different from the cement board density made from shavings (b2) and the mixture of flours and shavings(b3).The results of research showed that the average air dry moisture content of cement board was 4,544%, oven dry moisture content was 8.482%, air dry density was0.542 g/ cm^3, oven dry density was 0.547 g/cm^3, water absorption was 21.15%, and thickness swelling was 25.45%

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Appendix 1. Research data'

App. 1.1. Air dry MC

Bamboo	Flour (b1)	Shaving (b2)	Mix. (b3)	Total
a1	4.44	2.95	3.57	10.96
a1	5.25	2.55	7.47	15.27
a1	5.55	3.36	4.08	12.99
a2	4.78	5.33	4.36	14.47
a2	2.60	4.26	4.22	11.08
a2	4.10	3.37	3.80	11.27
a3	3.28	4.62	7.28	15.18
a3	7.80	3.71	3.71	15.22
a3	9.59	3.37	3.29	16.25
Total	47.39	33.52	41.78	122.69

App. 1.2. Oven dry MC

Bamboo	Flour (b1)	Shaving (b2)	Mix (b3)	Total
a1	7.84	7.04	8.19	23.07
a1	8.83	7.03	9.37	25.23
a1	9.03	7.22	8.16	24.41
a2	10.87	9.76	8.54	29.17
a2	6.53	8.98	8.45	23.96
a2	10.75	7.98	8.18	26.91
a3	8.38	4.40	10.08	22.86
a3	12.28	6.55	8.01	26.84
a3	12.73	7.45	6.38	26.56
Total	87.24	66.41	75.36	229.01

App. 1.3. Air dry density

Bamboo	Flour (b1)	Shaving (b2)	Mix. (b3)	Total
a1	0.73	0.40	0.48	1.61
a1	0.64	0.46	0.42	1.52
a1	0.86	0.53	0.40	1.79
a2	0.68	0.43	0.40	1.51
a2	0.87	0.39	0.44	1.70
a2	0.56	0.40	0.55	1.51
a3	0.65	0.43	0.37	1.45
a3	0.73	0.58	0.50	1.81
a3	0.60	0.59	0.55	1.74
Total	6.32	4.21	4.11	14.64

App. 1.4. Oven dry density

Bamboo	Flour (b1)	Shaving (b2)	Mix. (b3)	Total
A1	0.73	0.44	0.48	1.65
A1	0.64	0.47	0.42	1.53
A1	0.77	0.53	0.40	1.70
A2	0.75	0.43	0.40	1.58
A2	0.87	0.39	0.44	1.70
A2	0.56	0.40	0.55	1.51
A3	0.65	0.43	0.44	1.52
A3	0.73	0.61	0.50	1.84
A3	0.60	0.59	0.55	1.74
Total	6.30	4.29	4.18	14.77

App. 1.5. Water absorption

Bamboo	Flour (b1)	Shaving (b2)	Mix. (b3)	Total
a1	28.25	19.38	27.78	75.41
a1	16.56	17.54	27.06	61.16
a1	23.01	32.41	17.34	72.76
a2	28.48	15.70	18.69	62.87
a2	18.63	26.44	22.69	67.76
a2	21.36	29.68	27.17	78.21
a3	13.43	24.70	6.67	44.80
a3	15.75	16.83	21.89	54.47
a3	18.81	16.23	18.52	53.56
Total	184.28	198.91	187.81	571.00

App. 1.6. Thickness swelling

Bamboo	Flour (b1)	Shaving (b2)	Mix. (b3)	Total
a1	19.77	25.85	15.96	61.58
a1	34.00	26.02	20.42	80.44
a1	37.28	17.66	18.08	73.02
a2	27.69	32.36	13.62	73.67
a2	30.97	14.74	14.74	60.45
a2	30.88	17.68	30.51	79.07
a3	25.43	28.64	33.42	87.49
a3	26.95	29.33	27.70	83.98
a3	13.31	29.85	24.20	67.36
Total	246.28	222.13	198.65	667.06

Appendix 2. Analisa of Variance

App. 2.1. Analysis of Variance for Air dry MC

Source	df	SS	MS	F	P
Bamboo	2	5.837	2.918	1.14	0.342
Particle	2	10.818	5.409	2.11	0.150
Bamboo*Particle	4	12.648	3.162	1.23	0.332
Error	18	46.159	2.564		
Total	26	75.461			

S = 1.60136 R-Sq = 38.83% R-Sq(adj) = 11.65%

App. 2.2. Analysis of Variance for Oven dry MC

Source	df	SS	MS	F	P
Bamboo	2	2.986	1493	0.69	0.514
Particle	2	24.264	12.132	5.61	0.013
Bamboo*Particle	4	19.46	4.865	2.25	0.104
Error	18	38.903	2.161		
Total	26	85.613			

S = 1.47013 R-Sq = 54.56% R-Sq(adj) = 34.36%

App. 2.3. Analysis of Variance for Air dry density

Source	df	SS	MS	F	P
Bamboo	2	0.00462	0.0023	0.30	0.746
Particle	2	0.34616	0.1731	22.23	0.000
Bamboo*Particle	4	0.03256	0.0081	1.05	0.411
Error	18	0.14013	0.0078		
Total	26	0.52347			

S = 0.0882337 R-Sq = 73.23% R-Sq(adj) = 61.33%

App. 2.4. Analysis of Variance for Oven dry density

Source	Df	SS	MS	F	P
Bamboo	2	0.00565	0.00283	0.45	0.643
Particle	2	0.31654	0.15827	25.33	0.000
Bamboo*Particle	4	0.00359	0.00898	1.44	0.263
Error	18	0.11247	0.00625		
Total	26	0.47056			

S = 0.0790452 R-Sq = 76.10% R-Sq(adj) = 65.48%

App. 2.5. Analysis of Variance for Water Absorption

Source	Df	SS	MS	F	P
Bamboo	2	234.43	117.22	3.25	0.063
Particle	2	12.95	6.48	0.18	0.837
Bamboo*Particle	4	16.12	4.03	0.11	0.977
Error	18	649.86	36.1		
Total	26	913.37			

S = 6.00861 R-Sq = 28.85% R-Sq(adj) = 0.00%

App. 2.6. Analysis of Variance for Thickness Swelling

Source	df	SS	MS	F	P
Bamboo	2	45.44	22.72	0.55	0.588
Particle	2	126.04	65.02	1.52	0.246
Bamboo*Particle	4	373.85	93.46	2.25	0.104
Error	18	748.31	41.57		
Total	26	1293.63			

S = 6.44768 R-Sq = 42.15% R-Sq(adj) = 16.45%