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Particle Cement Board Quality from Corn Cob (Zea Mays L.) Based on Differences In Particle Size

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A R T I C L E I N F O

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A B S T R A C T

Utilization of agricultural waste is still lacking as raw material for biocomposites, so efforts are needed to use it, 1 of which is the manufacture of cement boards made from corn cobs. The aim of the study was to determine the effect of differences in the size of corn cob particles on the quality of cement particle board. The study was conducted with 3 treatments and 5 repetitions, namely treatment P1 (20 mesh), treatment P2 (40 mesh) and treatment P3 (50 mesh), using a ratio of cement to particles (3:1) with a pressing time of 20 minutes and pressure 40 bars. The research method refers to ISO 8335 (1987), BS 5669 (1989), MS 934 (1986) and SNI 8299 (2017) standards which include testing of physical properties (Density, Moisture Content, Water Absorption and Thickness Swelling) and mechanical properties including testing the Modulus of Elasticity (MoE), Modulus of Rupture (MoR) and Internal Bonding Strength (IBS). Analysis of research data using a completely randomized design (CRD). ANOVA analysis showed that the effect of the treatment of differences in the size of corn cob particles was very significant on testing the water content, water absorption, Modulus of Rupture (MoR). Internal Bonding Strength (IBS) is significant. Has no significant effect on density testing, thickness growth and Modulus of Elasticity (MoE). The best physical properties were density 1.164 g/cm^3(P3), moisture content 10.057% (P3), water absorption 11.630% (P3) and thickness swelling1.413% (P3) while the best mechanical properties were MoE 2,814.758 N/mm^2 (P1), MoR 4.926 N/mm^2(P3), and IBS 0.794 N/mm^2 (P3)

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INTRODUCTION

Cement board is a product made from wood waste or other lignocellulosic materials with cement as an adhesive and is processed by pressing. One of the lignocellulosic materials is corn cob which is a waste from corn plants which is widely used by farmers as fuel (Ardinal 2020). However, corncob can also be used as an ingredient in the manufacture of particle cement boards, considering that there are still many corn cobs that become waste because they are rarely used.

LITERATURE REVIEW

In the manufacture of particle cement boards, many factors affect the quality of the particle cement boards, namely particle size, catalyst ratio and so on. Saraswati, et al. (2018) stated that the treatment of material composition and treatment of particle size affected density, water absorption, moisture content, MoE and MoR. However, particle size did not affect water absorption. The interactions that occur between the composition of the material and the size of the particles affect the water absorption, moisture content, density, MoE and MoR.

Some of the applicable standards for the physical and mechanical properties of particle cement board are International standards ISO 8335 (1987), British standards BS 5569 (1989) and MS 936 (1986) respectively shown in Table 1 below:

Table 1. Physical and Mechanical Properties of Particle Cement Board Based on ISO 8335 (1987) and MS 934 (1986)

Properties of Particle Cement Board	Value	Unit
Density	1	g/cm^3
Thickness	6-40	mm
Moisture content	6-12	%
Water absorption	<30	%
Thickness swelling	<2	%
Modulus of Rupture (MoR)	>9	N/mm^2
Modulus of Rupture (MoR) after 24 hours of immersion	>5.5	N/mm^2
Modulus of Elasticity (MoE)	>3,000	N/mm^2

Source: ISO 8335 (1987) and MS 934 (1986) in (Fahmi and Zainuri, 2017).

Factors Influencing the properties of Particle Cement Board are type of wood, extractive substances, shape and size of particles, composition of particles with cement, board density, drying time, effect of pressure, other factors.

The shape and size of the particles of raw materials used such as chips, flakes, and sawdust can affect the properties of the particle cement board, this is because the material determines the size and shape of the particles to be used in the manufacture of particle cement board (Fahmi and Zainuri, 2017).

METHODOLOGY

The materials used are portland cement with the brand name Tonasa Cement (PCC) type II, $CaC1_2$-$2H_2O$ (Calcium Chloride Dihydrate) catalyst as much as 3% by weight of cement, and water to dissolve the catalyst.

The equipment used is a grinder (Hammer-mill Machine), molds with a size of 30 x 30 x 1.2 cm, limiting sticks, wooden racks, press machines, flasks, thermometers, plastic cups, measuring cups, ovens, water baths, petri dishes, desiccators, calipers, scales, equipment for mixing particles with cement (mixer), Universal Testing Machine (UTM), soaking tub, and millimeter paper.

Particle cement boardmanufacturing process as show below:

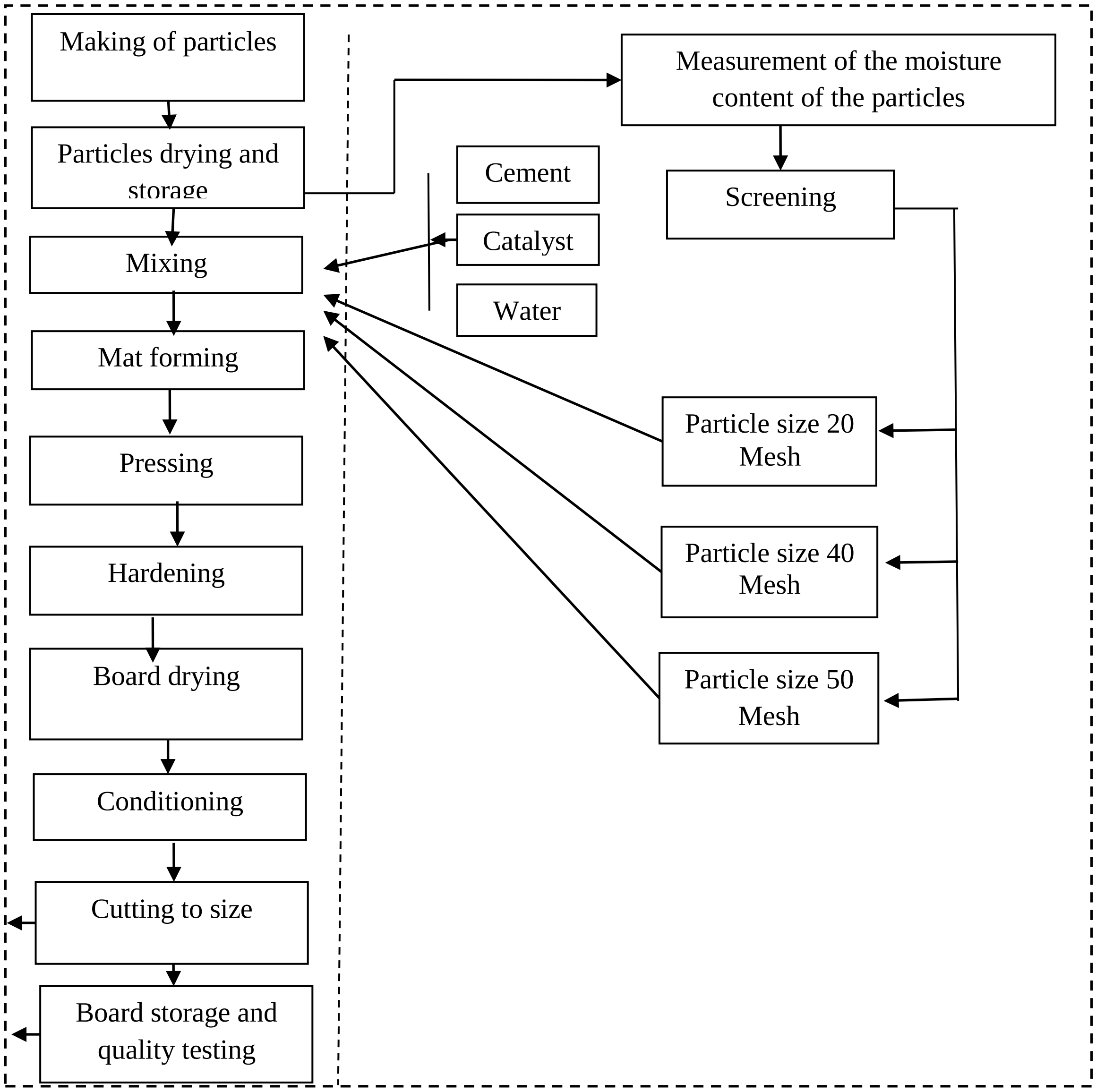

Figure 1. Particle Cement Board Manufacturing Process (Fahmi and Zainuri, 2017)

Tests were carried out based on four test standards, namely ISO 8335 (1987), BS 5669 (1989), MS 934 (1986) and SNI 8299 (2017) covering tests of physical properties, namely density, moisture content, water absorption and thickness swelling, as well as testing of mechanical properties, namely modulus of elasticity (MoE), modulus of rupture (MoR) and internal bonding strentgh (IBS).

1. Testing the Physical Properties of Corn Cob Particle Cement Boards

1.1. Density (ISO 8335 (1987))

$$\rho_o = \frac{m_o}{v_o} \, (g/cm^3)$$

po = dry cement board cement particle density (g/cm^3)
mo = dry mass of test sample (g)
vo = dry volume of test sample (cm^3)

1.2. Moisture content (ISO 8335 (1987))

$$\mu = \frac{m_n - m_0}{m_0} \times 100\%$$

μ = normal moisture content (%)
mn = normal mass of the test sample (g)
mo = dry mass of test sample (g)

1.3. Water absorption(MS 934 (1986))

$$\tau = \frac{m_1 - m_0}{m_0} \times 100\%$$

τ = Water absorption (%)
m1 = Mass of the test sample after soaking (g)
mo = Mass of test sample before soaking (g)

1.4. Thickness swelling (ISO 8335 (1987))

$$\alpha = \frac{t_1 - t_o}{t_o} \times 100\%$$

α = Thickness swelling (%)
t1 = Thickness of the test sample after soaking (mm)
to = Thickness of the test sample before soaking (mm)

2. Testing the Mechanical Properties of Corn Cob Particle Cement Boards

2.1. Modulus of Elastisity (MoE) (ISO 8335 (1987))

$$\epsilon b = \frac{\Delta F . l^3}{\Delta f . a^3 . b . 4} \, (N/mm^2)$$

ϵb = Modulus of elasticity (MoE) (N/mm^2)
ΔF = Change at the limit of proportion (N)
a = Thickness of test sample (mm)
b = Width of test sample (mm)
Δf = Deflection at the limit of proportion (mm)

l = Support distance (mm)

2.2. Modulus of Rupture (MoR) (ISO 8335 (1987))

$$\beta b = \frac{Fmax . l . 3}{a^2 . b . 2} (N/mm^2)$$

βb = Modulus of Rupture (MoR) (N/mm^2)

Fmax = maximum load/amount of force (N)

a = Thickness of test sample (mm)

b = Width of test sample (mm)

l = Support distance (mm)

2.3. Internal Bonding Strength (IBS)(BS 5669 (1989))

$$Qibs = \frac{Fmax}{A} (N/mm^2)$$

Qibs = Internal Bonding Strength (IBS) (N/mm^2)

Fmax = maximum load/amount of force (N)

A = Test cross-sectional area (mm2)

Data were processed using a completely randomized design (CRD) with 5 treatments and 5 repetitions for each treatment. As a treatment factor, the following particle size ratio is used:

P1 = 20 mesh particle size

P2 = 40 mesh particle size

P3 = 50 mesh particle size

RESULTS

1. Physical Properties of Corn Cob Particle Cement Boards

1.1. Density

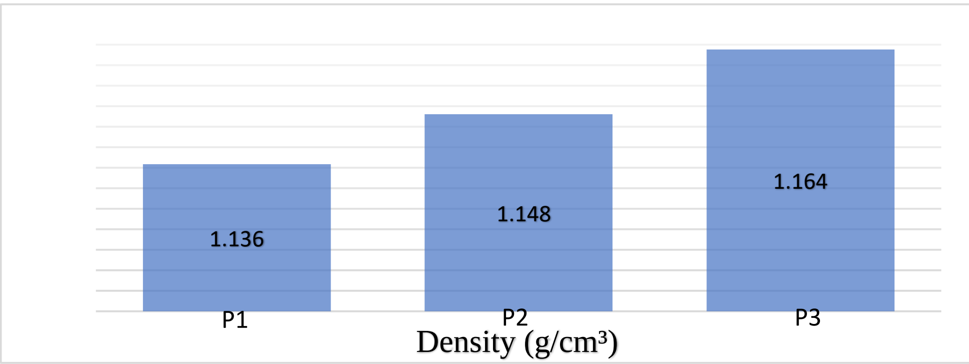

Figure 2. Density of Corn Cob Particle Cement Board

1.2. Moisture content

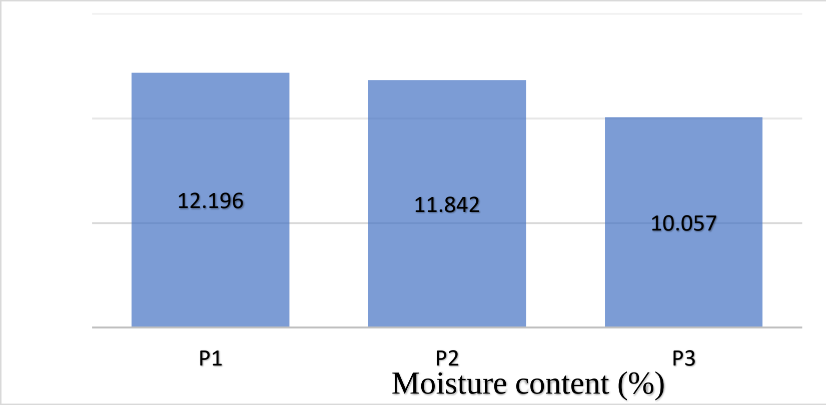

Figure 3. Moisture Content of Corn Cob Particle Cement Board

1.3. Water absorption

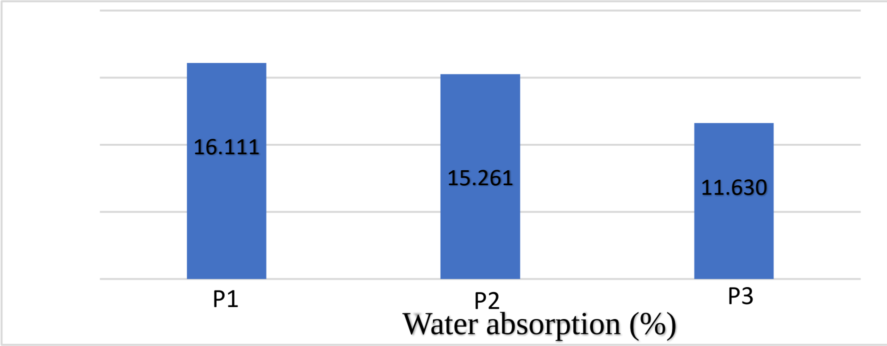

Figure 4. Water Absorptionof Corn Cob Particle Cement Board

1.4. Thickness swelling

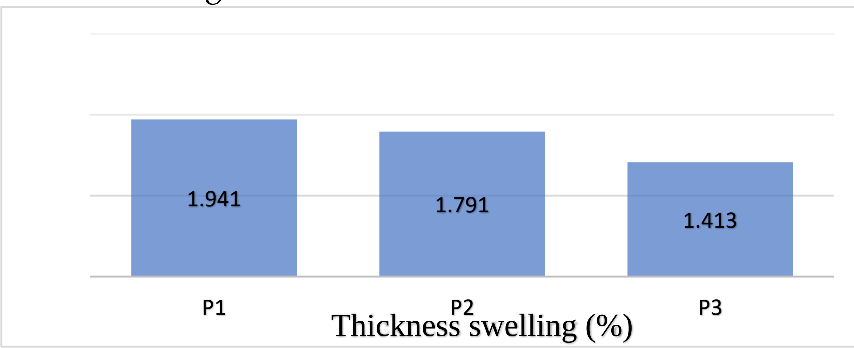

Figure 4. Thickness Swelling of Corn Cob Particle Cement Board

2. Mechanical Properties of Corn Cob Particle Cement Boards

2.1. Modulus of Elastisity (MoE)

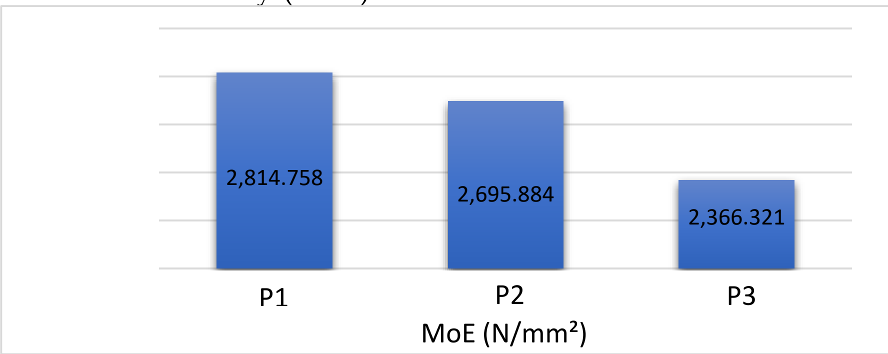

Figure 5. Modulus of Elasticity (MoE) of Corn Cob Particle Cement Board

2.2. Modulus of Rupture (MoR)

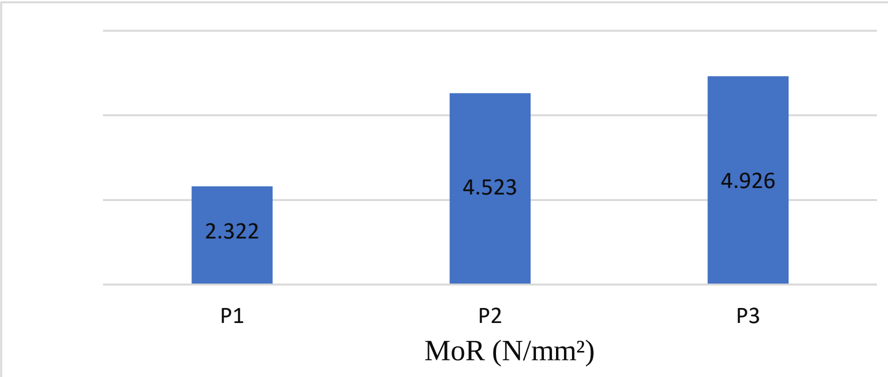

Figure 6. Modulus of Rupture (MoR) of Corn Cob Particle Cement Board

2.3. Internal Bonding Strength (IBS)

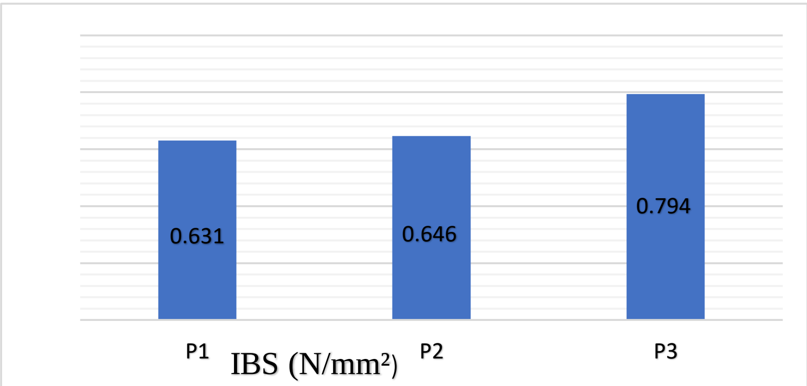

Figure 6. Internal Bonding Strength (IBS) of Corn Cob Particle Cement Board

DISCUSSION

Based on data from the research results, each test value is compared with the standard used to assess the quality of particle cement board, as shown in the following table.

Table 2. Comparison of the Value of Corncob Particle Cement Board Testing Against StandardsISO 8335 (1987) and MS 934 (1986)

	Corn cob particle cement board	ISO 8335 (1987) and MS 934 (1986)	Remark
Density (gr/cm^3)	1.164	1	Has fulfilled
Moisture content (%)	10.057	6 - 12	Has fulfilled
Water absorption (%)	11.630	<30	Has fulfilled
Thickness swelling(%)	1.413	<2	Has fulfilled
Modulus elasticity (MoE) (N/mm^2)	2,814.758	>3,000	Not fulfilled
Modulus of Rupture (MoR) (N/mm^2)	4.926	>9	Not fulfilled
Internal Bonding Strength (IBS) (N/mm^2)	0.794	-	No remark

Based on the data in Table 2, all the results of testing the physical properties of the corn cob particle cement board met the standards, but not all the results of the mechanical properties testing. This shows that mechanically, the corncob particle cement board is not good at holding loads, especially when used for structural purposes, but its physical condition is quite good.

Using analysis of variance (ANOVA) it can be seen the effect of the treatment of corncob particle size in particle cement boards on all test results which can be seen in Table 3 below.

Table 3. The Results of the Analysis of Variance (ANOVA) on the Effect of the Treatment of Corn Cob Particle Size in Particle Cement Boards on Each Result of Physical and Mechanical Testing

F-count value for each physical and mechanical test	Treatment of corncob particle size		
	Very significant	Significant	Not significant
Density (0.412)			ns
Moisture content (7.514)	**		
Water absorption (7.738)	**		
Thickness swelling(1.367)			ns
Modulus elasticity (MoE) (3.058)			ns
Modulus of Rupture (MoR) (40.769)	**		
Internal Bonding Strength (IBS) (4.683)		*	

Remark: Value of F-Table at Confidence Levels 95% (3.885) and 99% (6.927)

Based on the results of Table 3 (ANOVA), it can be seen that the treatment of corncob particle size has no significant effect on the particle cement board density value. This is presumably because the ratio of cement to particles is quite high (70:30) so that the amount of cement is more dominant in determining the weight of the board compared to the weight of the particles including their size.

Meanwhile the treatment of corncob particle size had a very significant effect on the value of the particle cement board moisture content. It is estimated that because the smaller particle size (50 mesh) absorbs less moisture than the larger particle size (20 mesh).

Also the results of the water absorption test were significantly influenced by the treatment of the corncob particle size. As is the case with testing for moisture content, smaller particle sizes (50 mesh) will absorb water less than larger particle sizes (20 mesh).

However, there is an interesting phenomenon, namely the thickness swelling test is not significantly affected by the particle size of corn cobs. This is expected because the high cement ratio (70:30) is able to withstand thick expansion even though water absorption increases or in other words the high cement ratio is able to eliminate the effect of particle size on the thickness swelling of particle cement board.

The particle size treatment has no significant effect on MoE or MoR. It is suspected that the ratio of cement to particles will have a more dominant effect than just particle size because a high cement composition will increase strength but reduce elasticity, conversely a high particle composition will reduce strength but increase elasticity of particle cement boards (Hutagaol, 2017).

The exception is IBS where particle size has a significant effect on IBS, this means that the internal bond between the cement and the particles in the particle cement board is affected by the size of the particles, the smaller the particle size (50 mesh) makes the cement bond better considering the specific surface of the small particles becomes larger, thus allowing the contact area or bond between cement and particles to be larger than larger particle sizes (20 mesh).

CONCLUSIONS AND RECOMMENDATIONS

Corn cob particle cement board with variations in particle size is good enough for physical properties but not good for mechanical properties so it is not suitable for structural use, but still good enough for non-structural use.

FURTHER STUDY

It would be interesting to carry out further research using treatments of variations in the ratio of cement to particles with the type of corn cob particles or other biomass

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