Characteristics of the cement board from parring bamboo (Gigantochloa atter)

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Abstract. As a non-timber forest product, bamboo is widely used as a craft material, construction, and food (bamboo shoots). Bamboo as a lignocellulose material can also be used as a raw material in the manufacture of cement boards. This research was conducted to compare the characteristics of the cement board derived from bamboo paring with various treatments. The type of bamboo used is bamboo paring (Gigantochloa atter), while the cement used is Portland Cement Composite (PCC). The cement board was made using conventional and CO₂ injection methods with the addition of additives (CaCl₂, MgCl₂, and Ca(OH)₂). The characteristics of the cement board were tested based on JIS A 5417-1992. The results showed that the addition of CaCl₂ using the CO₂ injection method significantly improved the physical and mechanical properties of the cement board.

1. Introduction
Nowadays, forests are no longer able to provide wood in large quantities and dimensions for industrial or building purposes. Therefore, wood processing technology has been being developed primarily to overcome the scarcity in large-dimensional timber, one of which is by producing cement boards. Due to cement board technology can use all lignocellulosic material, bamboo plants have the potential to be developed as raw materials. Bamboo is a plant that can regenerate itself without having to be planted, and it can be harvested in a relatively short time compared to wood [1].

A number of studies on bamboo as a raw material for cement boards have been carried out [2, 3, 4, 5, 6], and found that hardening of cement boards bamboo is better than pine wood [3]. However, cement boards from bamboo generally fail to achieve good modulus of elasticity [2, 7, 8]. Bamboo is a monocot species that is known to have a high extractive substance. Meanwhile, extractive is known as inhibitors in cement hardening [9, 10, 11].

Soaking in water is an effective method to reduce the soluble components of bamboo [11]. Addition of additives can also be a barrier to extractive substances and simultaneously accelerate the hardening of the cement in the curing [10, 12, 13]. Besides, the cement board curing process is often done in a long time even though an accelerator has been added. To overcome this, CO₂ injection is carried out, and it successfully accelerated the curing process from 28 days to one hour [14].

As stated, cement boards from bamboo have not been able to produce boards with great mechanical properties even though CO₂ injection treatment has been applied. In addition to CO₂ injection, the addition of an accelerator might be able to improve the strength of bamboo cement boards. Therefore, this study intends to examine the characteristics of bamboo cement boards with CO₂ injection method and the addition of accelerator material.
2. Method

2.1 Materials
The lignocellulose material used in this study was parring bamboo (*Gigantochloa atter*), obtained from Maros Regency, South Sulawesi Province. This material was ground in a mill to obtain particles that passed through a 20 mesh screen and retained on a 40 mesh screen. Cement used as an adhesive is a type of Portland Composite Cement (PCC) produced by PT. Semen Tonasa Pangkep, water used as a solvent obtained from water managed by PDAM Kota Makassar and additives [CaCl₂, MgCl₂, and Ca(OH)₂].

2.2 Board manufacturing and CO₂ injection
The cement board was made with a ratio of particles of wood, cement, and water is 1: 2.5: 1.25. Each board was made with a target density of 1.2 g/cm³ and a target thickness of 1 cm. The dough is prepared by mixing bamboo, cement, water, and additives [CaCl₂, MgCl₂ dan Ca(OH)₂] or without additives. This additive is applied to levels of 2% based on the weight of cement. The dough is mixed until homogeneous. The dough was made by mixing lignocellulose particles, cement and water until homogeneous. The mixture was then printed in a mold measuring 25 cm x 25 cm x 1 cm on an iron plate coated with transparent plastic. The mixture that has been prepared, put into iron plate printing then pressed to a thickness of 1 cm. The iron plate containing the pressed mixture is isolated around it and left at room temperature for 24 hours to reach the setting process.

After 24 hours, the board that has undergone the setting process is then given further treatment with conventional methods and CO₂ injection. For conventional methods, the board is placed in an open place for 28 days. For the CO₂ injection method, wood is injected with CO₂ for 60 minutes to reach curing. CO₂ injection is done by first inserting the board into the injection tube. In the tube, CO₂ flows. The condition was then maintained for 60 minutes. After that, the board is removed from the tube and put in the desiccator for ± 15 minutes. The board was then weighed and conditioned at 80°C 10 hours.

2.3 Testing
The boards produced from the conventional method and CO₂ injection are then tested to be tested for physical and mechanical properties concerning the Japanese Industrial Standard (JIS) A 5417-1992 [15]. Besides JIS A 5417 - 1992, the standard was used according to Bison's patent [16]. Testing physical properties include; density, moisture content, water absorption, thickness swelling, and linear expansion while testing mechanical properties include modulus of rupture (MoR), modulus of elasticity (MoE), and internal bond.

3. Result and discussion
Density describes the amount of board mass per unit volume. Figure 1 shows the density of the cement board made of bamboo. Based on these images, a board with CO₂ injection and the addition of CaCl₂ accelerator produced the highest density value, namely 1.17 g/cm³, whereas CO₂ injection board is the lowest, 0.99 g/cm³. In general, all the boards produced had not reached the target density, which is 1.2 g/cm³. It means that a lot of mixtures, ~cement, particles or water, have not yet reached the optimal amount to achieve the target.
Uniquely, the board with the CO$_2$ injection has a slightly lower density compared to conventional. Whereas, CO$_2$ injection is one method to increase the strength of the board by stimulating the formation of calcium carbonate (CaCO$_3$), especially in the curing stage [17]. Meanwhile, the board densities tend to increase with the addition of additives, respectively, from high to low, namely CaCl$_2$, MgCl$_2$, and Ca(OH)$_2$. It shows that the optimal board hydration process occurs in the CO$_2$ injection with the addition of CaCl$_2$.

The moisture content of the board, as presented in Figure 2, shows that the conventional cement board has the highest water content, which is 6.50%. Meanwhile, all boards with CO$_2$ injection showed that water contents tend to be low, ranging from 1.75 to 4.53%. Water content testing on the CO$_2$ injection method was done immediately after conditioning the boards at 80ºC for 10 hours. During the process, the board continues to release water so that the amount of water decreases continuously. It is
the reason why the water content of the cement board is low. Research Bakri and Suhasman [8] showed that the moisture content of the bamboo paring cement board with CO\textsubscript{2} injected method was 3.25%.

![Figure 3. Water absorption of the paring bamboo cement boards](image)

![Figure 4. Thickness swelling of the paring bamboo cement boards](image)

Water absorption and thickness swelling of the boards after soaking in water for 24 hours are presented in Figures 3 and 4. The board with CO\textsubscript{2} injection shows the lowest performance both in water absorption and thickness swelling, i.e., 50.2 and 64.24%, respectively. As with density, water absorption and thickness swelling have lower characteristics compared to the conventional method.

Meanwhile, the board has proper water absorption and thickness swelling when added with an accelerator. Moreover, MgCl\textsubscript{2} additive results in the smallest thickness swelling. It is different from the results achieved by Hermawan et al. [17], where MgCl\textsubscript{2} did not have a negative effect on the cement board, but it decreases the dimensional stability of the cement board.
As the physical properties, the CO\textsubscript{2} injection consistently shows poor performance, including modulus of rupture. This board can only produce MOR of 10 kg/cm\textsuperscript{2}, or 9 kg/cm\textsuperscript{2} smaller than conventional. It contrasts to the CO\textsubscript{2} injection board with the addition of additives, in which all three show good results. CO\textsubscript{2} injection board with the addition of CaCl\textsubscript{2} produces the highest MOR value, which is 71 kg/cm\textsuperscript{2}. Meanwhile, the boards with the addition of MgCl\textsubscript{2} and Ca(OH)\textsubscript{2} were 60 and 53 kg/cm\textsuperscript{2}, respectively.

![Figure 5. Modulus of Rupture (MOR) of the parring bamboo cement boards](image)

![Figure 6. Modulus of Elasticity (MOE) of the parring bamboo cement boards](image)
Meanwhile, the modulus of elasticity and internal bond shows a similar tendency with the modulus of rupture. Boards with CO$_2$ injection have the lowest modulus of elasticity and internal bond. Meanwhile, CO$_2$ injection board with the addition of CaCl$_2$ produces the best MOE and IB, which is 22,964 kg/cm$^2$ and 3.38 kg/cm$^2$.

Based on the description above, in producing cement board from bamboo, using CO$_2$ injection only cannot improve the strength of the cement board. The board tends to have worse characteristics compared to conventional boards. However, the addition of additives such as CaCl$_2$, MgCl$_2$, and Ca(OH)$_2$ showed a pretty good board performance. Some additives such as calcium chloride (CaCl$_2$), magnesium chloride (MgCl$_2$) and calcium hydroxide (Ca(OH)$_2$) were mentioned to minimize obstacles in hardening cement boards [13].

The MgCl$_2$ additive can make the board more stable, which is characterized by the smallest thickness swelling while CaCl$_2$ can produce a strong board. CaCl$_2$ can prevent or minimize the effect of losses by extractives and dissolved sugars and also harden the hardening and setting of semen [12]. The results of a study conducted by Moslemi et al. [13] also showed that in testing the hydration temperature of Pinus contorta, the addition of CaCl$_2$ was able to produce the highest hydration temperature value, i.e., 67ºC. Meanwhile, the hydration temperatures of MgCl$_2$ and Ca(OH)$_2$ were lower, namely 63.3 and 47.2 ºC, respectively.

In general, bamboo cement board with CO$_2$ injection method and CaCl$_2$ addition has high strength. This board meets almost all JIS A 5417 1992 standards except density whose value was still smaller than 1.2 g / cm$^3$. Mechanical and physical properties required by the standard are water content, density, thickness development, MOR and MOE with values of ≤16%, ≥ 1.2 g / cm$^3$, ≤8.3, ≥ 63 kg / cm$^2$, and 24,000 kg / cm$^2$, respectively. The density of the cement board is possible to be increased, and generally, the increase in density will be followed by an increase in the strength of wood [18].

4. Conclusion

Parring bamboo (Gigantochloa atter) has the potential to be used as raw material for cement boards. Bamboo cement board with CO$_2$ injection method and CaCl$_2$ addition shows the best characteristics and fulfills almost all the standards provided by JIS A 5417 1992 except density.
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