Characteristics of the Cement Board Using CO\textsubscript{2} Injection Technology from Wood and Non-Wood Species.

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Abstract. The fundamental weakness of the technology in manufacturing cement board is that the curing process takes a long time, which is about 28 days. CO\textsubscript{2} injection technology has been shown to accelerate the hardening process. However, each of the wood species has a different response due to the presence of inhibitors, namely extractive component. This study aims to compare the characteristics of CO\textsubscript{2} injection cement boards from three wood species. These three species came from hardwood, softwood, and non-wood groups, namely agathis (Agathis sp.), Gmelin (Gmelina arborea) and parring bamboo (Gigantochloa atter), respectively. The type of cement used was Portland Cement Composite (PCC). The three cement boards were made using the CO\textsubscript{2} injection method. The characteristics of the cement board were tested according to JIS A 5417 – 1992. The results showed that agathis has good characteristics in terms of mechanical properties. Both Internal bonding and modulus of elasticity were better than others, but not with its modulus of rapture. As for physical properties, parring bamboo actually showed good performance. However, in general, these three species of cement boards did not meet the standard.

1. Introduction

Cement board is panel products made by combining wood particles or lignocellulose, cement, and water formed by pressing under certain conditions. The raw material used for the manufacture of this product has a wide range in the form of whole wood, as well as other lignocellulose materials such as bamboo, coconut fiber, bagasse, kenaf, hemp, and others. This cement board product can mainly replace plywood and solid wood boards both of which use whole wood raw materials.

Cement boards are potential to be developed as building components that are more economical and more environmentally friendly so that they can be reached by low-income people. Related to this problem, what is interesting to develop is the manufacture of cement boards with CO\textsubscript{2} injection technology where this technology can shorten the curing time from previously reaching four weeks to just about one hour. In this process, the injected carbon dioxide will be neutralized quickly by calcium silicate to form carbonate calcium [1], and of course, this makes the cement board denser.

In Indonesia, the development of cement boards is very potential, because in addition to abundant available lignocellulose materials, cement production capacity is also very large, reaching 60 million tons in 2012 and is projected to continue to increase to 75 million tons in 2015 [2]. However, not all lignocellulosic materials can be used as raw material for cement boards due to differences in extractive substances they contain so that the choice of raw materials is limited. In many studies conducted, it was found that in several types of wood containing extractive substances in large proportions, it was able to
inhibit the process of setting on cement boards which were characterized by low temperatures of hydration and long hydration times.

Some of the results of research that have been conducted show that the type of raw material used affects the quality of the cement board produced as well. As with conventional cement boards, certain types of cement cannot be used as raw material for cement board construction because the chemical components that make up the soluble wood inhibit the cement hydration process. Therefore, a considerable amount of research has been developed to investigate the compatibility between cement and lignocellulose material.

Research that uses lignocellulosic material in the form of wood and non-wood has also been done. However, no one has compared the use of lignocellulosic material as a raw material for making cement boards using the CO$_2$ injection method. The lignocellulose material used is wood and non-wood particles. The wood particles used are wood originating from community forests. Consisting of gmelina wood to represent hardwood, and agathis to represent softwood. Non-wood lignocellulose material represented by bamboo. This study aims to compare the use of lignocellulosic wood and non-wood materials in the manufacture of cement boards using the CO$_2$ injection method.

2. Research Method

2.1. Materials

The lignocellulose material used in this study was agathis (Agathis sp.), Gmelina (Gmelina arborea) and parring bamboo (Gigantochloa atter), obtained from Maros Regency, South Sulawesi Province. This material was ground in mill to obtain particles that pass through a 20 mesh screen and retained on a 40 mesh screen. Cement used as a matrix is a type of Portland Composite Cement (PCC) available on the local market in Makassar while the water used as a solvent is obtained from water managed by PDAM Kota Makassar.

2.2. Board manufacturing and CO$_2$ 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/cm$^3$ and a target thickness of 1 cm. The dough was made by mixing lignocellulose particles (wood or bamboo), 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 in the mold on the iron plate was 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 was then given a CO$_2$ injection treatment. Wood is injected CO$_2$ for 60 minutes to reach curing. CO$_2$ injection is done by first inserting the board into the injection tube. In the tube, CO$_2$ 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 CO$_2$ injection are then tested to be tested for physical and mechanical properties concerning the Japanese Industrial Standard (JIS) A 5417-1992 [3]. Besides JIS A 5417 - 1992, the standard was used according to Bison's patent [4]. 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. Results and Discussion

Comparison of the characteristics of the cement board where the lignocellulosic material comes from softwood (Agathis), hardwood (Gmelina) and non-wood (Bamboo parring). The three boards are made
using the CO₂ injection method. The characteristics of the cement board tested in this study were the physical and mechanical properties of the cement board. Comparison of these characteristics can be seen as follows:

3.1. Physical Characteristics of Cement Board

3.1.1. Water content

The moisture content of particle wood and non-wood cement board is shown in Figure 1. The non-wood particle cement board has a higher moisture content (3.65%) than the wood particle cement board. Research conducted by Bakri and Suhasman [5] also showed that Bamboo paring is a type of bamboo that has the highest water content compared to other species of bamboo. The cement board of hardwood (Gmelina) has a lower moisture content (0.67%) compared to softwood cement board (Agathis) of 1.87%. Suhasman [6] in his research compared Gmelina wood with other wood species. The water content of Gmelina wood obtained is 7.18%, but the method used is different because this study uses a conventional method with the addition of CaCl₂. While the research was conducted by 7.2%. However, the three cement boards still have water content below 16%. Based on JIS A 5417-1992 which requires the board's water content to be a maximum of 16%, the three types of cement board made meet these standards.

![Figure 1. Water content of cement board particle wood (Agathis and Gmelina) and non-wood (Bamboo paring).](image)

3.1.2. Density

The density values of wood and non-wood particle cement boards are shown in Figure 2. The non-wood and wide hardwood particle cement boards have a higher density, each 0.95 g/cm², and 0.94 g/cm², compared to softwood particle cement boards. However, none of the three cement board samples reached the desired density value of 1.2 g/cm³. It is because the thickness of the three boards tested exceeds the set target of 1 cm, while the average thickness of the board is 1.26 cm. As a result of the volume of the board also becomes larger, so that the three boards have a low density and far below the desired target. Bakri and Suhasman [5] stated that another possibility is that the board thickness exceeds the desired target is the setting of the hydration process only for 24 hours, while there is still water left on the cement board. This water is still used for the hydration process to get the maximum amount of calcium silicate (maximum amount of calcium silicate hydrate) for 28 days at room temperature.
3.1.3. Water absorption

The results of the measurement of water absorption on wood and non-wood particle cement boards are shown in Figure 3. The value of water absorption on cement boards soaked for 2 hours ranged from 49.96 - 47.51%. The value of water absorption on cement boards soaked for 24 hours ranged from 54.65 - 50.20%.

The value of water absorption of non-wood particle cement board (from 2 times, 2 hours and 24 hours) obtained lower than the water absorption of wood particle cement board. Meanwhile, the value of the water absorption of softwood particles is higher than the water absorption capacity of cement boards of hardwood particles. According to Muharam [7] the closer the contact between particles, the more water vapor will be harder to get into the particle board. So that the higher the density, the more absorption the water will be. It is in line with the results of the density value in Figure 2, where the density of non-wood particle cement boards is high so that the water absorption is low.

![Figure 2. The density of cement board particle wood (agathis and gmelina) and non-wood (bamboo parring).](image)
Figure 3. The water absorption of cement board particle wood (Agathis and Gmelina) and non-wood (Bamboo parring).

3.1.4. Thickness swelling and linear expansion

The value of thickness swelling and linear expansion cement boards soaked in water for 2 hours and 24 hours is shown in Figure 4. The thickness swelling and linear expansion cement boards of hardwood particles soaked for 2 hours are higher than the cement board of softwood and non-wood particles. The value of thickness swelling and linear expansion softwood particles cement soaked for 24 is lower than that of hardwood and non-wood particle cement boards.

Riyadi [8] suspects that there is a relationship between water absorption and thickness swelling. It is because the more water is absorbed and enters the fiber structure, the more significant the change in dimensions produced. However, the thickness swelling and linear expansion values obtained on wood and non-wood particle cement boards in this study are inversely proportional to water absorption.
3.2. Mechanical properties of cement board

3.2.1. Internal bond

The internal bond values of wood and non-wood particle cement boards are shown in Figure 5. The internal bond values of cement hardwood and non-wood wood particles are lower (0.6 kgf/cm² and 0.8 kgf/cm² respectively) compared to softwood particle cement boards (1.5 kgf/cm²). Based on JIS A 5417-1992 which requires a minimum adhesive strength of 3.10 kgf/cm², there is none of the sticky firmness (IB) cement board for wood and non-wood particles that meet this standard. The same thing happened in the study conducted by Bakri and Suhasman [5] and Suhasman [6] where each of them examined bamboo cement boards (0.41 kgf/cm²) and gmelina cement board (1.34 kgf/cm²).

Figure 4. The thickness swelling and linear expansion of cement board particle wood (Agathis and Gmelina) and non-wood (Bamboo paring).
3.2.2. Modulus of rupture (MoR)

The modulus of rupture (MoR) cement board of wood and non-wood particle are shown in Figure 6. The calculation results obtained from the MoR cement board wood particle is higher (16 kgf/cm$^2$ and 19 kgf/cm$^2$) when compared to MoR cement board of non-wood particle. Based on JIS A 5417-1992 which requires a minimum MoR value of 63 kgf/cm$^2$, the MOR value of wood and non-wood particle cement boards does not meet these standards. It is caused by the board density value that does not meet the desired target of 1.2 g/cm$^3$, and 80.37 kgf/cm$^2$.

![Graph showing MoR comparison]

**Figure 5.** The Internal Bond of cement board particle wood (Agathis and Gmelina) and non-wood (Bamboo parring).

**Figure 6.** The modulus of rupture (MoR) of cement board particle wood (Agathis and Gmelina) and non-wood (Bamboo parring).
3.2.3. Modulus of Elasticity (MoE)

The MoE values of wood and non-wood particle cement boards are shown in Figure 7. The calculation results showed that MoE value of cement board from softwood is higher (3835 kgf/cm²) compared to MoE of cement board from hardwood and non-wood wood particles (each 2292 kgf/cm² and 2083 kgf/cm²). Research using the same material (bamboo parring and gmelina) was also carried out by Bakri and Suhasman [5] and Suhasman [6] with results of 2338.82 kgf/cm² and 13784 kgf/cm² respectively.

![Figure 7. The modulus of elasticity (MoE) of cement board particle wood (Agathis and Gmelina) and non-wood (Bamboo parring).](image)

The MoE value of the three cement boards does not meet Bison's commercial standards. Where the standard requires the MoE value of the cement board to be more than 30000kgf / cm² [4].

4. Conclusion

- Agathis has good characteristics in terms of mechanical properties.
- Both Internal bonding and modulus of elasticity were better than others, but not with its modulus of rupture.
- For physical properties, parring bamboo actually showed good performance. However, in general, these three species of cement boards did not meet the standard.

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