Characteristics of Cement Board with CO₂ Injection Method added CaCl₂ as Additive Using Two Wood Species from Community Forests

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Abstract. Wood from community forests has been calculated as one of the raw materials in the manufacture of cement boards. On the other hand, efforts to improve the compatibility of raw materials continue to be carried out, one of which is through the addition of additives. This additive can improve the characteristics of the cement board. The use of CO₂ injection method has been able to accelerate the curing process by about one hour compared to conventional methods. This research was conducted to compare the characteristics of conventional cement board and CO₂ injection methods using, each of which added CaCl₂. The wood species used were Acacia mangium (Acacia) and Arthophyllum diversifolium (Lento-lento). The type of cement used was Portland Cement Composite (PCC). The characteristics of the cement board were tested according to JIS A 5417-1992. The results showed that the Acacia cement board using conventional methods had better board characteristics than the CO₂ injection method. On the other hand, the Lento-lento cement board with CO₂ injection method produces better board characteristics.

1. Introduction

Many artificial boards are found on the market. This board is made as a way to utilize wood waste and also to reduce the use of solid wood. One of the many artificial boards on the market is the cement board. Cement board is a panel product or one type of composite board that uses raw material from lignocellulose material which is glued with Portland cement adhesive [1,2]. Some cement board products that have grown widely, both in developed and developing countries include cement-bonded wood wool boards, cement-bonded particleboards, and cement boards with fiber reinforcement (cement boards) [3].

Cement boards are very suitable for exterior and interior walls. Cement boards have resistance to fire, termites, and water. Besides that, the cement board is also accessible in machining or machining, making its products, and has excellent sound insulation properties [3,4].

In the manufacture of cement boards, the three primary materials used are particles of lignocellulose, cement, and water. The lignocellulose raw material in the production of cement boards can be wood waste, agricultural or industrial waste containing fiber. If using wood waste, the waste must be made in the form of particles. The wood used is wood that has a low density [5,6].
According to Prayitno [7], two fundamental factors influence the properties of the cement board. The first factor is wood and lignocellulose material as raw material and cement as the adhesive, including the type of wood used, density, particle dimensions used, extractive content, moisture content, type form and level of cement used. The second factor is the manufacturing process includes the intended density, catalyst or chemicals that function as hardeners.

The compatibility of wood raw materials with cement adhesives due to the presence of sugar content and lignosulfonates which can inhibit curing setting is a significant problem in the manufacture of cement boards [8]. One method that can be used to accelerate the hardening of the cement board is the administration of a catalyst (accelerator). The catalyst is an additive mixed in cement which has a function to increase the binding capacity of the binding material to wood particles so that an optimum bond is reached, accelerating the evaporation of water from the cement board, so that the process of hardening the board becomes faster and better results are obtained. Calcium chloride (CaCl$_2$) is a reasonably good catalyst if used in hardening cement boards using raw materials of wood powder [2,9]. On the other hand, the manufacture of cement boards using conventional methods requires at least 28 days to achieve a perfect curing process. The CO$_2$ injection method can accelerate the hardening process faster than conventional methods.

In Indonesia, one source of lignocellulose raw material can be obtained from wood waste originating from community forests. The types of timber used in the community forests include gmelina, lento-lento, pulai, and acacia. Comparison of the physical and mechanical properties of the cement board using conventional methods and injection of CO$_2$, each of which was added with CaCl$_2$ where the raw material came from community forests. This research was conducted to compare the characteristics of conventional cement board methods and CO$_2$ injection, each of which was added by CaCl$_2$ to two types of wood from community forests. The challenge faced in the development of local wheat is not easy because farmers and field workers have not fully controlled wheat technology from upstream to downstream, there is no market that can accommodate farmers 'harvest, lack of farmers' facilities and capital and lack of government support because wheat is not a commodity priority. However, based on the opportunities mentioned above, then it is proper for wheat to be developed based on the region's potential by finding varieties of wheat that are by Indonesia's agro climate.

2. Research Method

This research was carried out at the Laboratory of Processing and Utilization of Forest Products, Faculty of Forestry, Hasanuddin University from July to August 2018. The materials used in this study included wood of Acacia mangium (Acacia) and Ascoyphyllum diversifolium (Lento-lento), which was obtained from around the education forest area of Hasanuddin University in Bengo-bengo, Maros Regency, South Sulawesi Province. 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 CaCl$_2$ additives.

The equipment used in this study included hammer mill, sieve 20 and 40 mesh, glove, oven, desiccator, plastic clip, grading spoon, digital scale with 0.01 g accuracy, stopwatch, 200 ml Erlenmeyer flask, petri dish, thermocouple , vacuum flask, plastic container, basin, gauze, mold measuring 25 cm x 25 cm x 1 cm, iron plate size 150 mm x 150 mm x 3 mm, plastic, aluminum foil, cold press, CO$_2$ injection tool, caliper, micrometer , Universal Testing Machine (UTM), calculators, cameras, and writing instruments.

The first stage carried out in this study was the manufacture of cement boards. The cement board is made with a ratio of particles of wood, cement, and water is 1: 2.5: 1.25. Each board is made with a target density of 1.2 g / cm$^3$ and a target thickness of 1 cm. The dough is prepared by mixing bamboo, cement, water, and additives (CaCl$_2$) particles until homogeneous. This additive is applied to levels of 2% based on the weight of cement. The mixture is then printed in a frame measuring 25 cm x 25 cm x 1 cm on an iron plate coated with transparent plastic. The mix that has been prepared in a frame on an iron plate is 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 then flows. The condition is 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 in an oven at 80°C for 10 hours.

The boards produced from the conventional method and CO₂ injection are then tested for physical and mechanical properties regarding the Japanese Industrial Standard (JIS) A 5417-1992 [10]. Testing physical properties include: density, moisture content, water absorption, expansion of thickness and linear, while testing mechanical properties include modulus of rupture (MoR), modulus of elasticity (MoE), and internal bond.

3. Results and Discussion
Two characteristics of the cement board tested to compare the cement board made using conventional methods, and cement boards using CO₂ injection method are the physical and mechanical properties. The comparison of these characteristics can be seen as follows:

3.1. Physical Characteristics of Cement Board
3.1.1. Water content
The board has hygroscopic properties of water from its environment, so the water content of the board is affected by the surrounding conditions when the board is stored. In other words, the water content is related to the water absorption ability in the cement board [8,11]. The water content of the cement board of acacia and lento-lento using conventional methods or CO₂ injection ranges from 1% - 8% (Figure 1). The water content of the traditional cement board is much higher than the moisture content of the cement board with CO₂ injection. Based on JIS A 5417-1992 which requires the board's water content to be a maximum of 16%, the four cement boards made meet these standards.

![Figure 1. The water content of the cement board using conventional and CO₂ injection methods](image)

The Palm fiber cement board with 3% CaCl₂ added with the composition of palm fiber and cement 1: 2 has lower water content (10.39%) compared to cement board made from the composition of palm fiber and cement 1: 1 without CaCl₂. The more cement composition and CaCl₂ levels increase the tendency for hygroscopic properties of water vapor on the cement board to decrease. It causes the cement board to become harder and stronger [12].

3.1.2. Density
JIS A 5417 - 1992 does not require a density value. However, in this study, the expected density value for a cement board is 1.2 g/cm³. Of the four board samples tested, only the acacia cement board using
conventional method whose density value approached the expected density was 1.18 g/cm$^3$ (Figure 2). The other three boards have a density less than the target set with an average board density of only 1 cm. The density value of the lento-lento cement board with CO$_2$ injection method is higher (1.15 g/cm$^3$) than the lento-lento cement board using a conventional method. On the contrary, the density value of the acacia cement board using conventional method is higher than that of the acacia cement board with the CO$_2$ injection method which is 1.18 g/cm$^3$. The density of the lento-lento cement board using conventional method is lower (1 g/cm$^3$) than acacia cement board using conventional methods. On the other hand, the density value of lento-lento cement board with CO$_2$ injection method is higher than that of acacia cement board with the CO$_2$ injection method (1.07 g/cm$^3$).

Purwanto [8] states that the nature of the raw particle material can increase the bond with cement and this is related to the high density of the cement board. The study conducted by Purwanto [12] stated that the treatment of cement composition and CaCl$_2$ levels affected the cement board density value. There is a tendency to increase the cement board density value by multiplying the cement ratio and CaCl$_2$ levels. This condition is possible because the pores are getting denser and the cement board produced is denser.

![Figure 2. The density of the cement board using conventional CO$_2$ and injection methods](image)

3.1.3. Water absorption

Water absorption and thick development are physical properties related to the stability of the dimensions of the cement board [13]. The results of the measurement of water absorption on the cement board of the lento-lento and acacia particles are shown in Figure 3. The value of water absorption on the cement board soaked for 2 hours (DS2) ranges from 3.09 - 37.01%. The value of water absorption on the cement boards soaked for 24 hours (DS1) ranged from 31.18 - 40.05%.

The value of water absorption of the lento-lento cement board using conventional method absorbed for 2 hours (DS1) is higher (18.63%) compared to the lento-lento cement board with CO$_2$ injection method. The lento-lento cement board using conventional method soaked for 24 hours (DS1) has a lower water absorption value (31.18%) compared to the lento-lento cement board with CO$_2$ injection method. The value of water absorption of the acacia cement board using conventional method absorbed for 2 hours (DS1) and soaked for 24 hours (DS2) obtained higher results (37.01% and 40.05% respectively) compared to the acacia cement board with the CO2 injection method.

The requirement for the value of cement board water absorption according to JIS A 5417 - 1992 is a maximum of 8.3%. The treatment that meets the needs of JIS A 5417-1992 is only the lento-lento cement board with CO$_2$ injection method which is immersed for 2 hours (3.09%). Bakri et al. [14] suggested the ratio of cement to raw materials affected the absorption of cement board water. Cement board with a ratio of cement to raw material 3: 1 produces a lower water absorption value than the ratio of cement to raw material 2: 1.
Figure 3. Water absorption of cement board using conventional and CO$_2$ injection methods

3.1.4. Expansion of Thickness and Linear

The value of expansion of thickness and linear cement boards soaked in water for 2 hours (P1) and 24 hours (P2) is shown in Figure 4. The value of expansion of thickness and linear the lento-lento cement board using conventional method soaked for 2 hours is higher than the lento-lento cement board with CO$_2$ injection method. The lento-lento cement board using conventional method soaked for 24 hours has the expansion of thickness and the linear value lower than the lento-lento cement board with CO$_2$ injection method. In the acacia cement board, the value of expansion of thickness and linear using conventional method soaked for 2 hours and 24 hours was lower than that of CO$_2$ injection method (0.95% and 3.74%, respectively).

The expansion of thickness and linear values obtained on the lento-lento cement board are directly proportional to water absorption. However, the expansion of thickness and linear values obtained on the acacia cement board are inversely proportional to water absorption.

Figure 4. Expansion of Thickness and Linear cement board using conventional and CO$_2$ injection methods

Several factors can cause expansion of thickness and linear. First, water absorption is thought to be related to thick expansion because the more water is absorbed and enters the fiber structure, the higher the change in dimensions produced. Large water absorption and high-water content will result in the expansion of large cement board thickness. Second, particle size geometry and increase in particle length. Third, the comparison of materials with cement and chemical auxiliary materials, in general, the higher cement content will reduce thick expansion, also the use of a mixture of raw and auxiliary materials [12, 13, 15].
3.2. Mechanical Properties of Cement Boards

3.2.1. Internal bond
The internal bond values (IB) of the lento-lento and acacia cement boards are shown in Figure 5. The internal bond values of the lento-lento and acacia cement board using conventional method were higher (3.44 kgf/cm² and 3.38 kgf/cm² respectively) compared to the lento-lento and acacia cement board with CO₂ injection method (3.30 kgf/cm² and 3.19 kgf/cm², respectively). Based on JIS A 5417-1992 which requires a minimum adhesive strength value of 3.10 kg/cm², the internal bond values of the lento-lento and acacia cement board have met these standards.

![Figure 5. Internal Bond cement board using conventional and CO₂ injection methods](image)

3.2.2. Modulus of rupture (MoR)
The modulus of rupture value of the lento-lento and acacia cement boards shown in Figure 6. The calculation results obtained are higher MoR values of the lento-lento cement board using the conventional method (65 kgf/cm²) when compared with the lento-lento cement board with CO₂ injection method. As with the lento-lento cement board, the MoR value of the acacia cement board using conventional method is higher than that of the acacia cement board with the CO₂ injection method (32 kgf/cm²). Based on JIS A 5417-1992 which requires a minimum MoR value of 63 kgf/cm², only the lento-lento cement board using conventional method meet this standard. According to Purwanto [12] stated that there was a tendency for an increase in MoR value caused by the addition of CaCl₂.

![Figure 6. Modulus of rupture (MoR) cement board using conventional and CO₂ injection methods](image)
3.2.3. **Modulus of Elasticity (MoE)**

The Modulus of Elasticity (MoE) value of the lento-lento and acacia cement board is shown in Figure 7. The calculation results showed that the MoE value of the lento-lento cement board using a conventional method was lower compared to the lento-lento cement board with CO₂ injection method (12988 kg/cm²). Meanwhile, MoE of the acacia cement board using a conventional method was higher (12293 kgf/cm²) compared to the MoE of the acacia cement board with the CO₂ injection method.

![Figure 7. Modulus of elasticity (MoE) cement board using conventional and CO₂ injection methods](image)

The requirements for the flexural strength of particle cement board according to JIS A 5417-1992 are at least 24000 kg / cm². If referring to this requirement, the four cement board treatments have not met JIS A 5417-1992 standard.

4. **Conclusion**

1. Cement board of *acacia* produced using conventional method has better board characteristics than one using CO₂ injection method.
2. CO₂ injection method produces better board characteristics in the *lento-lento* cement board.
3. Both cement boards have not met the standards for JIS A 5417-1992 (MoR and IB)

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