Physical and mechanical properties of cement-bonded particleboard made from squander of paper

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Abstract. The objectives of this study were to assess and explain the usage of squander paper as a selective crude material in the production of cement-bonded particleboard (CBP) and to decide its physical and mechanical properties. The two treatment factors were used such as squander of paper types (A4 paper sheets, newspaper and cardboard) and CaCl2 as chemical accelerator agents (in concentrations of 2%, 4% and 6% according to the weight of cement) with proportions mixed of cement - squander of paper - water about 2.5:1:1.25. The result indicated that the squander of paper types and the concentration of CaCl2 have affected the physical and mechanical properties of CBP. The board which produced using cardboard with the proportions of materials (2.5:1:1.25) and accelerator CaCl2 about of 6% were satisfied all the requirement standard of JIS A 5417 1992 and have the most physical and mechanical properties values.

1. Introduction

One of the composite board items that are effortlessly made is the cement board which uses cement as covers while the crude material can be either wooden particles or particles of lignocelluloses material. Unfortunately, being developed of cement board items, explicitly cement-bonded particleboard (CBP) faced with the state of the accessibility of wood as crude material have begun restricted, so it turns into an extraordinary research to search for the best answer to resolve it in the forthcoming. The utilization of selective material as crude materials for CBP is one of the promising arrangements. Squander of paper is a material that is conceivably. Squander of paper will be paper that has not been utilized again in its utilization so it is bound to be disposed or reused around the world. Squander is the remainder of the fixings in utilization by people. Paper is daunting material and the subsequent midpoints with pressure of fiber that comes from the mash drying work insight in addition to some extra material that adheres to one another and each other's weaves. Fiber ordinarily utilized common fiber generally containing cellulose and hemicellulose. Though some lignocelluloses material may show some level of contrariness with cement on the manufacture of CBP, there are arrangement the procedures to assess the level of contradiction, which are either thermal characteristics of a cement setting measure or on the physical and mechanical properties of the cement board made in the laboratory, when contrasted with similar boundaries yet got with a slick water-cement combination. On account of an unsatisfactory level of inconsistency, eliminated dissolvable compound by conventional hot or cold water extraction and splashing, respectively,1-5 long-term putting away of the crude material,6 numerous substance extraction methods7-9 and even treatment by fungi10 might be sufficient to redesign the crude material to the ideal level. Likewise, the expansion of modest quantity of cement
setting quickening agents (accelerators), similar to the chlorides of tin, iron, aluminum, magnesium\(^{(11)}\) or calcium\(^{(12,13)}\) have the impact on improving the compatibility. They can be applied to make quicker the setting of cement, improving the physical and mechanical properties of the composites, or delivering a given wood types reasonable for making composites with cement. In addition, accelerator empowers the response happens all the more rapidly or permit the response at lower temperatures because of changes that set off against reactant. During the time spent making of CBP, the kind of accelerator utilized was derived from the chloride salts, such as CaCl\(_2\).

The objectives of this research were to assess and explain the usage of squander paper as an selective crude material and CaCl\(_2\) as an accelerator in the production of CBP and discover the most physical and mechanical properties of CBP.

2. Methods

2.1 Materials

Mixtures with proportionally equal amounts of squander paper particles (HVS paper sheets, newspaper and cardboard) were utilized to manufacture CBP. The average size of the squander paper particles was 3 mm (L), 2 mm (W), and 0.2 mm (T). Ordinary Portland cement of TONASA was utilized as a binder and CaCl\(_2\) was used as an accelerator.

2.2 Manufacture and Evaluation of CBP

CBP with a targeted density of 1.2 g/cm\(^3\) was manufactured at a cement/squander paper particle/water weight proportion of 2.5:1.0:1.25. Hand-framed mats of 30 x 30 cm were cold pressed to a targeted thickness of 12 mm and kept in an oven-dry set at 60\(^\circ\)C for 4 h. Subsequently, CBP was wrapped with a polyvinylchloride (PVC) film immediately, followed by curing for 24 hours and afterward conditioning at room temperature (1 week) prior to property evaluation. The manufacturing process of CBP as mentioned at Figure 1. The physical and mechanical properties of the boards were tested in accordance with the Japan Industrial Standard (JIS) A 5908 (1994). The boards were cut into 50 x 50 mm samples for density, thickness swelling (TS), water absorption (WA) tests as well as the internal bond (IB) strength tests, and 50 x 210 mm samples for the static bending test. The static bending test was conducted using a three-point bending test over an effective span of 180 mm (15 times the board thickness) at a loading speed of 10 mm/min. Four test samples were prepared from each treatment group for the foregoing tests, and the average values were calculated.

2.3. Statistical Analysis

For statistical data analysis, this study was conducted using the Multiple Linear Regression model with two independent variables, in particular the squander paper types which consists of three levels, namely A4 paper sheets, newspaper and cardboard; and CaCl\(_2\) as chemical accelerator agent comprises of three levels, namely 2%, 4% and 6%. In addition, the values obtained were also compared with the JIS A 5417 1992 standards so that the test boundaries that meet these standards are known.
3. Results and discussion

3.1. Physical Properties

The result showed in Figure 2 that the density of the CBP made from squander of paper ranges from 1.18-1.22 gr/cm³. Such the most density value of 1.22 gr/cm³ obtained on the CBP - A3B3 with the proportion of 2.5:1: 1,25 were utilized cardboard and accelerator CaCl₂ of 6%, while the least density value of 1.18 gr/cm³ obtained on board A1B1, A1B2 and A2B1 which used HVS paper sheet and accelerator CaCl₂ of 2% and 4% as well as newspaper used accelerator CaCl₂ of 2% followed by advanced hardening time for 2 weeks.
The results show that the density of CBP produced using different squander of paper is not vastly different, and it is upheld during the time spent making cement board load up where the heaviness of materials are the equivalent. The presence of contrasts of density is just brought about by the distinction of the thickness of the end sheets. Despite the fact that to accomplish target 1.2 cm in thickness of CBP and to accomplish consistency of thick sheets have additionally utilized a steel stick as 12 mm. Furthermore, the accelerator concentration of CaCl₂ 6% is the optimum concentration used in the process of making cement boards because with this concentration can accelerate the bond between cement as crude materials with squander paper, particularly for cardboard material and reinforce ties as well as the hardening of the materials. However, the physical properties change as representative of WA and TS values of CBP after 24 h of water soaking are appeared in Figure 3 and Figure 4. Significant correlations were observed between the WA and TS and treatment conditions of CBP under the board manufacture proportion treatment of 2.5:1:1.25. The lowest average WA and TS values were 15.24% and 0.25%, respectively, at CBP produced using cardboard having accelerator CaCl₂ of 6%. This phenomenon indicated that CBP made from cardboard using accelerator CaCl₂ of 6% may result in increasing the dimensional stability, apparently through decreased water absorption ability. For this research, the density, water absorption and thickness values of CBP met the JIS A 5417 1992 standard limits.

![Figure 3. Water absorption test of CBP made from various squander of paper and CaCl₂](image1)

![Figure 4. Thickness swelling test of CBP made from various squander of paper and CaCl₂](image2)

### 3.2. Mechanical Properties

The average values for the IB strength of CBP cured with conventional curing condition is presented in Figure 5. The linear relationship was found between the concentration of CaCl₂ as an accelerator and the IB strength of CBP. With the increase of concentration of CaCl₂ within about 6%, the IB values of CBP were significantly increased. The maximum average IB value of CBP made by cardboard was 1.42 MPa after conventional curing treatment. This condition with the proportion of materials such as 2.5:1:1.25 and treated by CaCl₂ about of 6% allowed rapid curing of CBP in the range of this experiment and contributed to increasing the IB strength of CBP. Furthermore, the IB value of CBP treated by CaCl₂ about of 6% and made by squander of cardboard after conventional curing was improved compared to others board. It should be noticed that CBP treated with CaCl₂ about of 6% and continued by conventional curing for 28 days then increased the IB strength. This result relevance with sufficient water for chemical reaction because of w/c ratio should around more than 30% (50%).
Figure 6 and Figure 7 show the modulus of rupture (MOR) and modulus of elasticity (MOE) values of CBP treated with some squander of papers and CaCl$_2$. The maximum average MOR and MOE values were 11.2 MPa and 5.1 GPa, respectively, at board made of cardboard having the CaCl$_2$ at around 6%. This finding shows that CaCl$_2$ at around 6% accelerated the curing process and enhanced the MOR and MOE of CBP. The MOR and MOE values of CBP made of cardboard having the CaCl$_2$ at around 6% increased and were remarkably higher than the values of such other boards. Compared to CBP treated with CaCl$_2$ below 6%, in which the CaCl$_2$ from around 2% to 4%, the MOR and MOE values were decreased and they gave a negative effect on board performances. This conditions affected by insufficient of CaCl$_2$ to react with cement which the w/c ratio 0.5, as mentioned earlier, decreasing the internal bending strength of CBP. Wei$^{(14)}$ and Moeslemi$^{(15)}$ also found that the CaCl$_2$ accelerator as an additive can be used to increase the adhesive power of cement against materials containing cellulose such as paper, wood and other materials. CaCl$_2$ catalyst is added to inorganic binders such as cement to improve the quality of the binder bonds to other materials and accelerate the hardening of the binder. In addition, it can reduce the inhibiting effect of materials such as paper or wood used on the hardening of Portland cement. The IB, MOR and MOE test results as described above, meet the minimum standards of JIS A 5417 1992.
4. Conclusions
The physical and mechanical properties of CBP are excellent by using squander of papers even after the conventional curing process. These properties, however, have good conditions of boards which made from cardboard. It was considered that CBP made from cardboard using accelerator CaCl$_2$ about of 6% may result in increasing the dimensional stability, through low of water absorption as well as thickness swelling ability such as 15.24% and 0.25%. The maximum average MOR and MOE values were 11.2 MPa and 5.1 GPa, respectively, were found at the same board which is made from cardboard using CaCl$_2$ at around 6%. It was consider that the proportion of materials and the squander of papers as well as the concentration of CaCl$_2$ have affected the physical and mechanical properties of CBP and satisfied all the requirement standard of JIS A 5417 1992.

5. Acknowledgments
The authors thank the Directorate of Higher Education; Ministry of National Education-Indonesia, Pattimura University Ambon for their finance support through the PNBP (Penerimaan Negara Bukan Pajak) in Top Research Areas Grant 2018.

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