

UTILIZATION OF EUCALYPTUS OIL REFINERIES WASTE FOR CEMENT PARTICLE BOARD

Rudi Setiadji* and Andriati Amir Husin

Experimental Station of Building Materials, Research Institute for Human Settlements

*Corresponding E-mail : kolaka_80@yahoo.com

ABSTRACT

Utilization of eucalyptus oil refinery waste in the manufacture of building material component of cement particle board is expected to reduce the price of housing units. This research used laboratory experimental methods, eucalyptus oil waste in the form of branches and twigs from eucalyptus tree. The variation of the testing were mixtures composition of the particle: cement, additives as accelerators, cold press load during manufacture of cement particle board. Cold press duration of cement board was 24 hours. The sizes of particle boards were (40 x 40) cm² and 13 mm thick. The samples were tested for its density, water content, water absorption, flexural strength, thickness swelling, adhesion strength, and the nails pull out strength.

Keywords: *Particle, Eucalyptus, Cement board*

1.0 INTRODUCTION

Prices of building materials can be reduced by use of basic materials derived from waste. Utilization of waste in this study was eucalyptus oil refinery waste in the form of eucalyptus twigs. Eucalyptus plant in Forest Stakeholder Unit (KPH) Indramayu were scattered at five sections of Forest Stakeholders Unit (BKPH). Based on existing data (KPH Perhutani Indramayu, 1999) sustaining areas for eucalyptus oil refineries were amounted to 5,300 hectares with an estimated production of eucalyptus leaves (DKP) at 3 tons/ha. The utilization for eucalyptus oil processing plant is 60 tons/day. Eucalyptus oil refinery waste form might be liquid, leaves, and eucalyptus wood. Details of the waste generated were 40% leaves for fuel, and 60% twigs with a diameter of 0.5 to 1 cm of 550 kg/ton dry. Means that in 60 ton/day oil refinery waste in the form of wood was 550 kg x 60 tons/day equivalent to 33,000 kg. Utilization of eucalyptus oil refinery waste as alternative raw materials for cement particle board is expected to reduce the price of housing units.



Figure 1: Landfill of eucalyptus oil refinery waste

Based on data from KPH Perhutani Indramayu, there are some eucalyptus oil factory in Indonesia which is under Perhutani and five are located in the island of Java, Sukabumi, Kuningan, Indramayu, Gundih, and Ponorogo. As example of the eucalyptus oil factory (PMKP) Jatimunggal in Indramayu has a production target which increases every year, 12,000 tons/year of eucalyptus oil were processed in 2008 and this factory was included as the largest in Southeast Asia. At present, all of the waste is used as a plantation compost. Eucalyptus oil produced from every 1 ton of material is equivalent to 7 kg. Most of the waste, approximately 6,000 tons/year, can be used for boiler fuel so that the average remaining 6,000 tons/year of waste that has not been exploited economically.

Based on previous research and available potential resources, there is a need for research about properties of cement bonded particle board with eucalyptus oil refinery waste and variation of chemicals additive that complied with standard requirements.

2.0 LITERATURE REVIEW

Many previous research on cement bonded particle board has been conducted. Aini [1] studied cement board with oil palm stem, the flexural strength only up to 14,36 kg/cm². It was predicted because of insufficient clamp load. Ashori et al. [2] described that there is a positive correlation between the compression ratio of wood materials and their bending strength. Alhedy et al. [3] studied the effect of water soaking periods of time, pressure levels, and cement/bamboo ratio. The effect of the three studied factors was dependent on each other for MOR and hardness. The results showed that all specimens met the specification of the British standard (BS 1105; 1972) for strength properties and the density of the product increased with increasing cement/bamboo ratio. Soaking in water for more than 7 or 10 days was either not significantly different from 3 days or had lower strength and density values; hence, no need for soaking in water for more than 3 days. Water absorption and dimension swelling decreased significantly with increasing cement/bamboo ratio. Also increasing of pressure from 0.05 kg/cm² to 0.15 kg/cm² did not improve the mechanical and physical properties, this may be due to the low pressure levels used in the study. Aggarwal [4] observed that when the casting of bagasse-cement samples was increased from 1 to 3 N/mm², there was about 32% increase in density (1.21 – 1.60 g/cm³) of the consolidated mass while 7.5% increase was observed when casting pressure was increased from 3 – 5 N/mm² for the same volume of bagasse-cement mix. The water absorption of the samples is from 19.5 to 13.4% and 13.4 to 11.6% when the casting pressure is increased from 1 to 3 N/mm² and 3 to 5 N/mm², respectively. The optimum casting pressure required for bagasse-cement samples is in the range of 2-3 N/mm².

Antonios N. P. [5] made cement bonded particleboards with hornbeam (*Carpinus betulus* L.) wood particles and CaCl₂ additive as 3%. Heat hydration test was done to gain the inhibitory index for characterizing the relationship between wood and cement. Results show that hornbeam-cement mixture can be classified as moderate inhibition. Wood : cement ratio used were 1 : 3 and 1 : 4. Increasing wood : cement ratio improved the characteristics of cement bonded particleboards except the modulus of rupture. Idris, A.A [6] studied cement bonded particleboards with reed fiber. Flexural strengths with lime immersion were in range of 40,18 – 70,66 kg/cm², while flexural strengths with water immersion were in range of 28,25 – 61,24 kg/cm².

Ling Fei Ma [7] concluded that there is a relationship between cement hydration with mechanical properties of cement board from wood and other lignocellulosic materials. Mechanical performances can be predicted from total of energy released from hydration process. Materials being used was wood chip of sugi, hinoki, kenaf, bamboo, rice hull, and rice straw. Cement portland type I has added with MgCl₂, Na₂CO₃, NaHCO₃, NaSiO₃, CaCl₂ additive as 0%, 2,5%, 5%, 10%, and 15%. Increasing additive content increased the modulus of elasticity and modulus of rupture with maximum additive content range between 5% to 10%.

Sudin and Swamy [8] made bamboo flakes and oil palm fibres, tested the sugar content, and its effect on strength development of cement Portland mixture. Accelerator materials used were CaCl₂, MgCl₂, Al₂(SO₄)₃, Al₂(SO₄)₃+Na₂SiO₃ as 2%, fly ash, rice husk ash, and latex for

cement partial replacement as 10%, 20%, and 30%. Bamboo-cement board with bamboo : cement ratio as 1 : 2,75 with aluminium sulphate additive as 2% complied with local standard MS 934 requirement. Oil palm fibre-cement board with cement replacement range between 10% to 20% satisfied the local standard MS 934 requirement.

3.0 METHODOLOGY

The research using laboratory experimental methods carried out in the Building Materials Department in Research Institute of Human Settlements of the Ministry of Public Works in Bandung. Waste eucalyptus branches and twigs were obtained from PMKP Jatimunggul Indramayu. Eucalyptus oil waste was tested for heat of hydration. The composition of the mixture between the particles : cement by mass were 1 : 3, 1 : 4 and 1 : 5. Additional materials as an accelerator were CaCl_2 , MgCl_2 , $\text{Al}_2(\text{SO}_4)_3$. Cold press loads during the process of cement particle board making were 20 kg/cm^2 , 25 kg/cm^2 , 40 kg/cm^2 and 50 kg/cm^2 . Cold press duration of cement board was 24 hours. The size of particle board was (40 x 40) cm^2 and 13 mm thick. The number of repetitions of each test were 3 times and were tested for density, water content, water absorption, flexural strength, thickness swelling, strong adhesion, and the nails pull out strength. The test results were compared with SNI 03-6861.1-2002 Building Material Specifications Part A (Non Metallic Building Materials) [9] and ISO 8335-1987 Standards of Cement-bonded Particleboard [10]. Eucalyptus wastes was crushed resulting of 4.8 mm maximum size. Physical properties of eucalyptus particles are given in Table 1

Table 1: Physical properties of eucalyptus particles

Properties	Results
Specific gravity	0.21
Water absorption	9.97 %
Water content	1.70 %

4.0 RESULTS AND DISCUSSIONS

4.1 HEAT OF HYDRATION

Inhibitory index of neat cement in Table 2 is lower than the index of eucalyptus particles–cement mixture, it shows that eucalyptus particles has wood-extractives that reduced the maximum hydration temperature. Time to maximum temperature of eucalyptus particles–cement mixture was reduced compared to the neat cement, contrary to a previous study by Ashori et al [2]. Particles size might have possible effect of wood-extractive, as finer particles expose more surface area to the cement paste and thus more extractives can enter into solution. Hydration test can be related to mechanical strength as research by Huceng Qi [11] on chromated copper arsenate (CCA)-treated wood-cement composite that with the increase of wood content, the maximum hydration temperature was decreased, and also the splitting tensile strength. But due to the effect of CaCl_2 , time to reach maximum hydration temperature for CCA-treated wood cement composite was even shorter than that of neat cement, same behaviour with the results in Table 2 from this eucalyptus-cement mixture study. Same result by Wei et al. [12] that there was a positive trend between hydration characteristic and strength of wood cement-based composite. The higher the T_{max} , the larger were the strength values of Modulus of Rupture (MOR) and Internal Bonding (IB).

The hydration test was carried out primarily to determine the effect of the accelerator in this study on the early hydration behaviour of cement. As given in Table 2 that mixture composition without accelerator have greater value of inhibitory index than mixture composition of neat cement, it shows that cement is not well hydrated eventough the cement content was

increased up to composition of cement to eucalyptus particles as 5 : 1 and the inhibitory index cannot be increased.

Accelerator addition as 2% is increased the inhibitory index, probably due to the capacity of the accelerator minimize the adverse effect of the inhibitory chemicals released from wood and also to accelerate the cement hardening and setting similar with experiment by Antonios [5]. The ideal material should provide higher maximum temperature and lower time to achieve the maximum temperature. Best performance for eucalyptus to cement composition is resulted from MgCl₂ followed by CaCl₂ addition. Maximum hydration time is reached faster with CaCl₂ addition. Addition of Al₂(SO₄)₃ is not recommended for eucalyptus particles to cement composition. Based on smallest inhibitory index and hydration time, all samples was made with composition of eucalyptus particle to cement as 4 : 1 with CaCl₂ addition as 2%.

Table 2: Heat of hydration test results

Eucalyptus particles : cement	Accelerator	<i>t</i> [hours]	<i>T</i> [°C]	<i>S</i>	<i>I</i>
0 : 1	-	8.0	28.2	0.27	0.000
1 : 3	-	6.5	27.3	0.10	0.893
1 : 4	-	6.5	27.3	0.10	0.893
1 : 5	-	6.5	27.3	0.10	0.893
1 : 4	CaCl ₂	5.0	28.9	0.13	- 0.140
1 : 4	MgCl ₂	7.0	29.0	0.20	- 0.409
1 : 4	Al ₂ (SO ₄) ₃	7.0	28.0	- 0.09	0.519

4.2 DENSITY OF CEMENT PARTICLES BOARD

Eucalyptus-cement board density ranged between 1200 – 1310 kg/m³, increasing of clamp load increased densities as given in Figure 2 due to the thickness is not limited by stopbar as the packing increased and volume decreased but the weight is relatively constant. Same result by Aggarwal [4] that the increase in casting pressure results in the formation of more compacted fibre-cement mass, thereby decreasing void volumes within samples and hence the thickness of the consolidated mass. In the case of bagasse-cement samples there was a continuous increase in density with the increase in casting pressure.

Density test results are given in Table 3. Samples density with stopbar treatment, clamp load as 20 kg/cm² and 25 kg/cm² are complied with SNI 03-6861.1-2002 requirement [9]. All samples are satisfied with the ISO 8335-1987 requirement [10]. There is a correlation between density and mechanical properties due to enhance wood densification, elimination of gaps, and improved connection between cement matrix and particles. Density, water absorption, and porosity are all interrelated physical properties. When particle content is increased, water absorption increases, whereas density decreases as seen in comparison of Figure 2 and Figure 3.

Clamping was done by Universal Testing Machine (UTM) for 24 hours and cured at room temperature. All samples thickness with stopbar greater than designed thickness as 13 mm, it was predicted because of less clamping duration so samples swelling back. Board thickness with clamp load as 25 kg/cm² is same with designed thickness so it can be used as the maximum clamp load of board without using 13 mm stopbar.

4.3 WATER ABSORPTION

Eucalyptus-cement board properties of water absorption ranged between 22 – 28%, increasing clamp load decreased the water content as given in Figure 3. High pressure from the

clamp minimize voids and reduce water infiltration. Wood particles have greatest absorption among board materials when exposed to water but clamp load may play dominant role in reducing this effect owing to more cement matrix coverage by pressure, leading to blocking the flow of water into wood particles. Higher clamp load results higher density and increasing density decreased water absorption same results by Aggarwal [4]. There is no requirement for maximum water absorption in SNI 03-6861.1-2002 [9] or ISO 8335-1987 [10].

4.4 WATER CONTENT

Eucalyptus-cement board water content ranged between 11.8 – 14.5%, increasing clamp load decreased water contents as given in Figure 4. Samples water content with clamp load are complied with ISO 8335-1987 maximum requirement as 12% [10] due to clamping pressure forced the water leak out. Cement particle board making with clamp load treatment results lower water content than cement particle board making with stopbar.

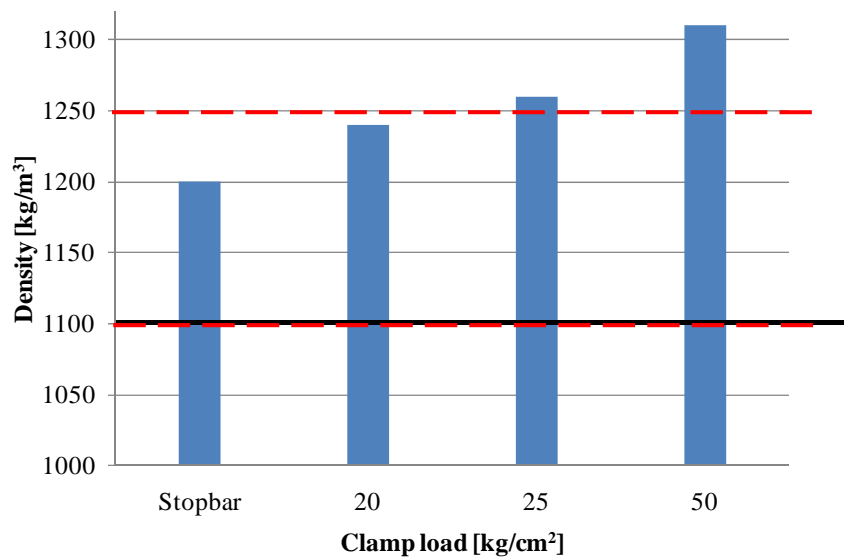


Figure 2: Density of cement-bonded eucalyptus particle board

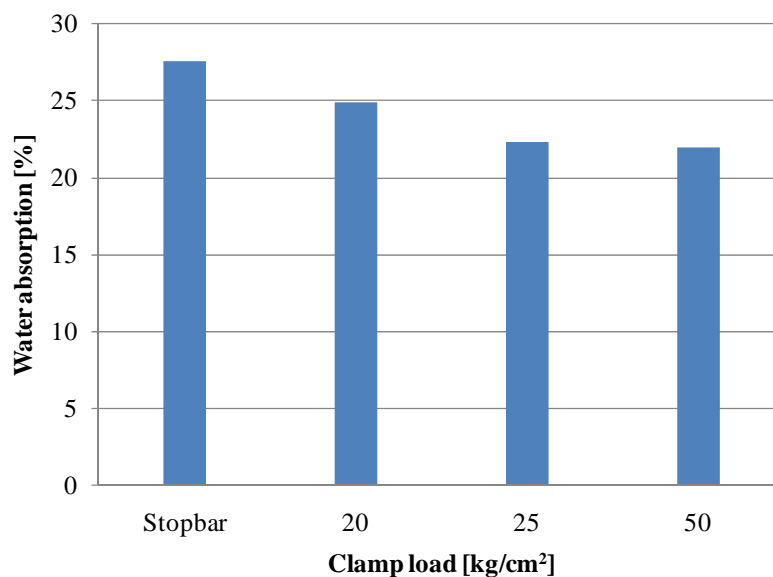


Figure 3: Water absorption of cement-bonded eucalyptus particle board

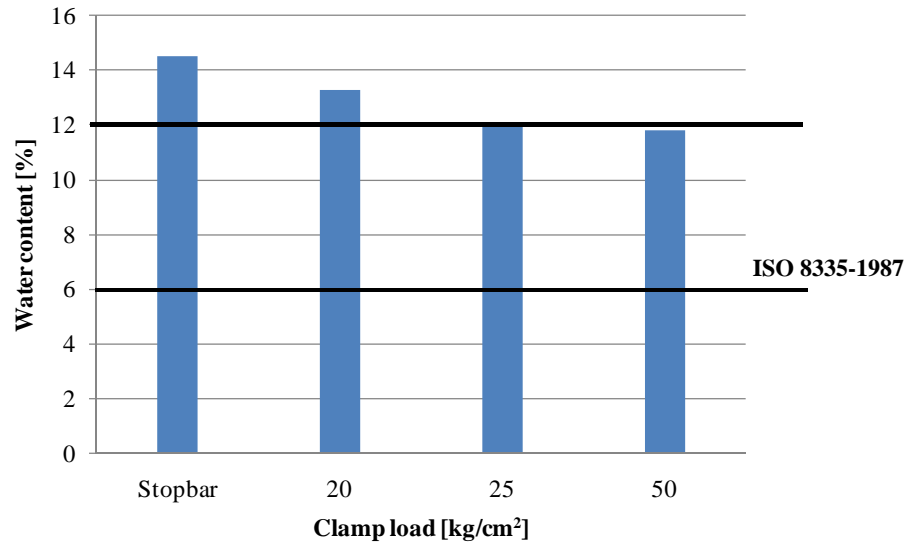


Figure 4: Water content of cement-bonded eucalyptus particle board

4.5 FLEXURAL STRENGTH

Eucalyptus-cement board flexural strength ranged between 22.84 – 47.82 N/mm² as showed in Figure 5. Cement bonded particle board samples is satisfied with SNI 03-6861.1-2002 requirement [9]. Increasing clamp load increased the flexural strength as given in Figure 5, probably bonds between samples materials composition increased as the clamp load increasing. Due to the pressure of the clamp load, frictional force are developed between particles and the cement matrix. When the system is loaded these frictional forces transmit stresses if the particles are embedded in the matrix over a sufficient length. Huceng Qi [11] stated that particle size has been shown to be a main effect on the strength properties. Non-ideal particle size such as thicker than the practical requirement and the fine particles which were not screened and discarded before the board manufacture would resulted low flexural strength. Eucalyptus particle maximum size used in this study was 4.8 mm and no fine particles discarded, so probably the size and gradation of particles was in ideal range and contributed to the flexural strength.

4.6 MODULUS OF ELASTICITY (MOE)

Eucalyptus-cement board MOE ranged between 1893.50 – 2467.00 N/mm² as showed in Figure 6. Ashori et al.[2] showed that percentage of wood-wool mixture, cement, and CaCl₂ and their interactions had significant effect on the MOR and MOE of the boards. Those three variabls were fixed in this study so the effect of clamp load can be studied. Increasing clamp load increased modulus of elasticity as given in Figure 6 but none of samples complied with standards. It is predicted that eucalyptus particles have low stiffness or low bond strength with cement. Other reason probably due to increasing clamp load increased density so modulus of elasticity also increased. Similar with Oyagade [13] resulted that board density was linearly and positively related to bending properties including Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) of cement bonded particleboard when cement/wood ratio was held constant.

4.7 THICKNESS SWELLING

Thickness swelling of cement-bonded eucalyptus particle board after soaked in water for 24 hours ranged from 0.13 to 0.38 % are complied with ISO 8335-1987 maximum requirement as

2% [10]. Semple and Evans [14] argue that thickness swelling is highly dependent on particle geometry. It increases with increasing particle thickness and decreasing particle length. The use of thicker particles results in greater heterogeneity and more irregular open board surface which is more easily penetrated by water. Rough surface and greater internal void space caused by the use of thicker particles are responsible for higher thickness swelling. Meneeis et al. [15] also mentioned that by using low cement-wood ratios, the wood particles are not encapsulated by cement, which results in low bonding and therefore in low internal bond values and increased thickness swelling. Based on those previous results, it is predicted that thin and short particle, enough cement-wood ratio, and high clamp load in this study increased the bonding strength and reduced the thickness swelling significantly.

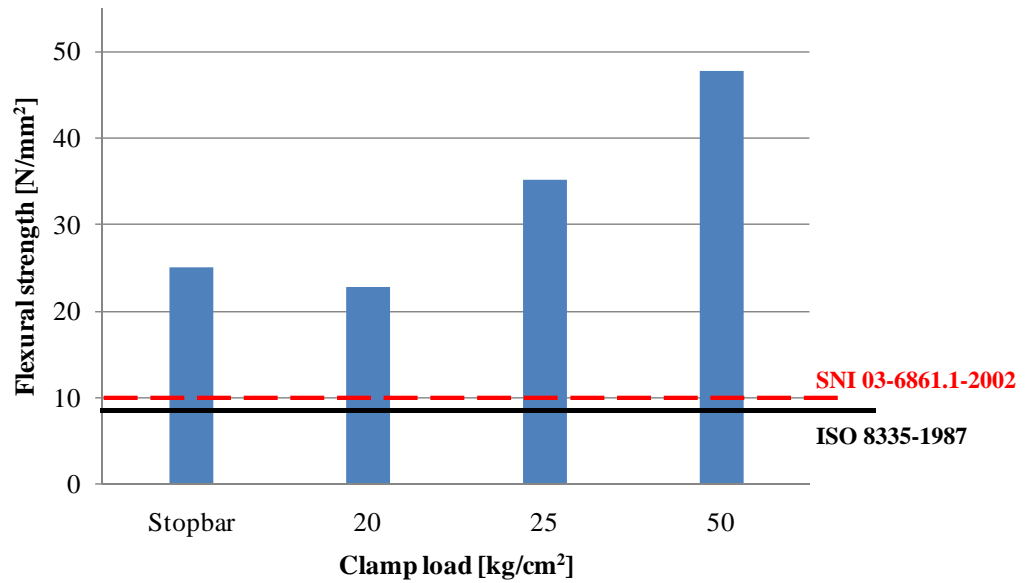


Figure 5: Flexural strength of cement-bonded eucalyptus particle board

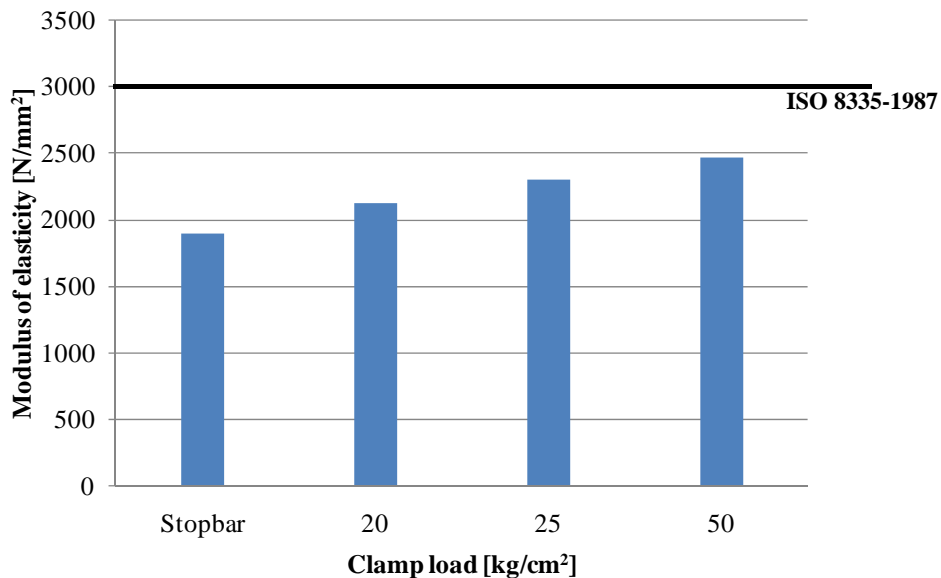


Figure 6: Modulus of elasticity of cement-bonded eucalyptus particle board

4.8 BOND STRENGTH

Eucalyptus-cement board bond strength ranged between 1.21 – 4.37 kg/cm² as showed in Figure 7. Bond strength can be affected by several factors. Huceng Qi [11] stated that bond strength reflects directly the bonding ability of portland cement, the quality of cement hydration, and the compatibility of CCA-treated wood with cement. Higher water/cement ratio contributed to higher bonding strength due to the better hydration of cement and improvement to the fine structure of hydrated cement product. Bond strength of cement-bonded eucalyptus particle board in this study that satisfied with SNI 03-6861.1-2002 requirement [9] only for samples with clamp load as 50 kg/cm² as given in Figure 8. It is assumed clamp load also affect the bond strength and clamp load as 50 kg/cm² would be the minimum value of clamp load for complied board.

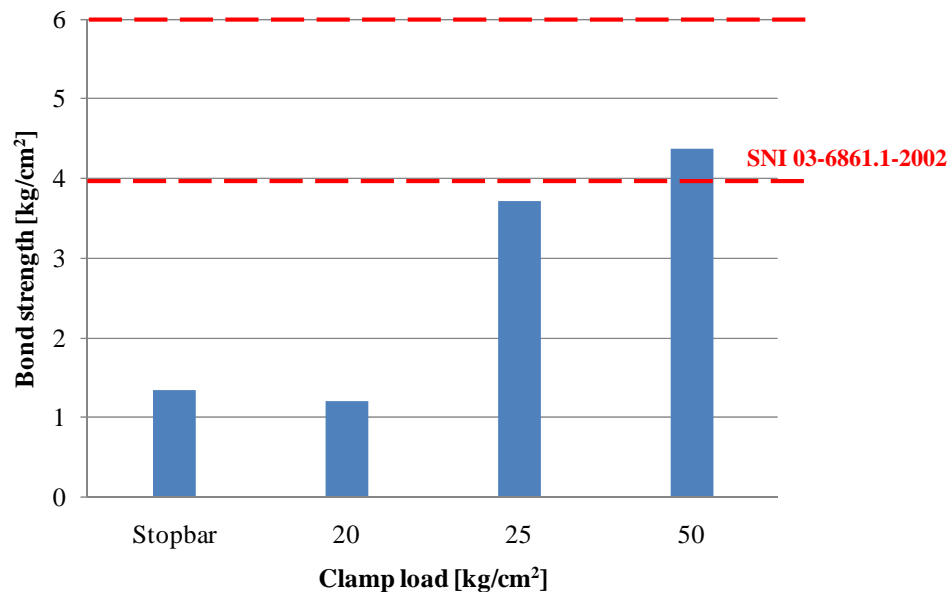


Figure 7: Bond strength of cement-bonded eucalyptus particle board

4.9 NAIL PULL OUT STRENGTH

It is explained in the Wood Handbook [16] that the strength and stability of any structure depend heavily on the fastenings that holds its parts together. Nails are the most common mechanical fastenings used in wood construction to resist withdrawal loads, lateral loads, or a combination of the two which affected by factors of the wood, the nail, and the condition of use. In general, any variation in these factor has a more pronounced effect on withdrawal resistance than on lateral resistance. The resistance of nail to direct withdrawal depends on the density of the wood product, the nail diameter, and depth of penetration. The nail diameter and depth of penetration in this study was conditioned to be uniform, so the density of the cement board defined. Nail pull out strength of of cement-bonded eucalyptus particle boards ranged between 45.00 – 60.33 kg as showed in Figure 8 and complied with SNI 03-6861.1-2002 requirement [9]. Increasing clamp load increased nail pull out strength as given in Figure 9, probably clamp load increased the density and improve frictions between eucalyptus cement board to nail.

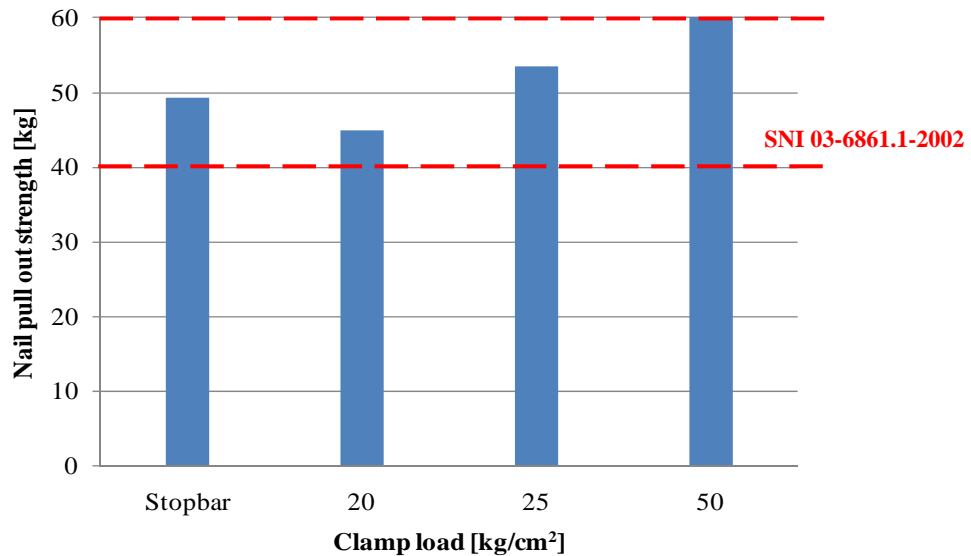


Figure 8: Nail pull out strength of cement-bonded eucalyptus particle board

5.0 CONCLUSIONS

Potential waste eucalyptus oil based on data from KPH Indramayu Perhutani are quite numerous and scattered in various locations in Indonesia. Material in the form of branches and twigs fairly easily obtained in terms of collecting, cleaning, and transportation. The heat of hydration test results showed that although the amount of cement was increased to the composition of eucalyptus fiber: cement at 1 : 5, it could not increase the inhibitory index. Inhibitory index was best for the composition of white cement-eucalyptus fiber using accelerator $MgCl_2$, and the maximum heat of hydration time was reached quickly by using $CaCl_2$, whereas $Al_2(SO_4)_3$ results was not optimal for the composition of the cement-eucalyptus fiber. Based on its density, samples was complied with SNI 03-6861.1-2002 except samples with cold press loads at 25 kg/cm² and 50 kg/cm². The value of water contents that meet the maximum 12% requirement was obtained with a cold press load at 50 kg/cm². Water absorptions were ranged between (22.0 to 27.6)% and the lowest value was obtained by cold press load at 50 kg/cm². The entire value of flexural strength specimens were complied with SNI 03-6861.1-2002 but the modulus of elasticity were not complied. Value of thickness swelling of the entire specimen thickness were ranged in (0.13 to 0.43)% and were qualified as the maximum value at 2%. Cold press load value at 50 kg/cm² could be the minimum boundary for eucalyptus cement board in order to get a strong adhesive that meets the requirements. Nails pull out strength were range in (45.00 to 60.33) kg, complied with SNI 03-6861.1-2002. Based on test results, it was concluded that all specimens of eucalyptus cement board in this study using a mixture of eucalyptus fiber : cement at 1 : 4 and additional materials as much as 2% $CaCl_2$ addition, resulted the best characteristics when combined with cold press load at 50 kg/cm².

ACKNOWLEDGEMENT

A gratitude and sincere appreciation are presented for the Research Institute of Human Settlements in Bandung, KPH Perhutani Indramayu, eucalyptus oil factory (PMKP) Jatimunggul in Indramayu for finance, materials, and test facilities support that have been provided.

REFERENCES

- [1] Aini, N (2002), “Pemanfaatan Limbah Sawit untuk Bahan/komponen Bangunan Perumahan”, Research Institute for Human Settlements, Bandung
- [2] Ashori, A., Tabarsa, T., Azizi, K., and Mirzabeygi, R. (2011), “Wood-wool Cement Board Using Mixture of Eucalypt and Poplar”, *Industrial Crops and Product*, Vol 34, pages : 1146 – 1149
- [3] Alhedy, A. M. A., Algadir, A. A. Y. A, and Mohamoud, A. E. A (2005), “Effect of Pretreatment and Pressure on Properties of Cement-bonded Products from *Oxytenanthera abyssinica*”, *Proceedings of the Meetings of the National Crop Husbandry Committee 40th*, pages :237-244
- [4] Aggarwal, L. K. (1995), “Bagasse-reinforced Cement Composites”, *Cement & Concrete Composites*, Vol 17, pages : 107-112
- [5] Antonios N. P. (2008), “Mechanical Properties and Decay Resistance of Hornbeam Cement Bonded Particleboards”, *Research Letters in Materials Science*, Vol 2008, Article ID 379749
- [6] Idris, A.A. (1994), “Penelitian Pemanfaatan Alang-alang sebagai Papan Semen”, *Jurnal Penelitian Peremukiman*, Vol 10, pages : 3-4, Research Institute for Human Settlements, Bandung
- [7] Ling Fei Ma (2005), “Manufacture of Bamboo-Cement Particleboard”, Institute of Wood Science and Technology, Zhejiang Forestry University, Linan, Zhejiang, China
- [8] Sudin, R., and Swamy (2006), “Bamboo and Wood Fibre Cement Composite for Sustainable Infrastructure Regeneration”, *Journal of Materials Science*, Vol 41, pages : 6917-6924
- [9] SNI 03-6861.1-2002, “Building Material Specifications Part A (Non Metallic Building Materials)”, National Standardization Agency
- [10] ISO 8335-1987, “Standards of Cement-bonded Particleboard”, International Organization for Standardization
- [11] Huceng Qi (2001), “Leaching, Hydration and Physical-mechanical Properties of Spent Chromated Copper Arsenate (CCA)-treated Wood-cement Composite”, Master Thesis, Graduate Department of Forestry, University of Toronto
- [12] Wei, Y. M., Zhou, Y. G., and Tomita, B. (2000), “Study of Hydration Behavior of Wood Cement-based Composite II : Effect of Chemical Additives on the Hydration Characteristics and Strength of Wood-cement Composites”, *J Wood Sci*, Vol 46, pages : 444-451
- [13] Oyagade, A. O. (1989), “Effect of Cement/wood Ratio on the Relationship Between Cement Bonded Particleboard Density and Bending Properties”, *Journal of Tropical Forest Science*, Vol 2(2), pages : 211-219
- [14] Semple, K. E, and Evans, P. D. (2007), “Manufacture of Wood-cement Composite from *Acacia Mangium*. Part II. Use of Accelerators in the Manufacture of Wood-wool Cement Boards from *A. Mangium*”, *Wood Fibre Sci*, Vol 39, pages : 120-131
- [15] Meneeis, C. H. S., Castro, V. G., and Souza, M. R. (2007), “Production and Properties of a Medium Density Wood-cement Boards Produced with Oriented Strands and Silica Fume”, *Maderas : Ciencia y tecnologia*, Vol 9(2), pages : 105-116
- [16] Risbrudt. C. D, Ritter. M. A., and Wegner. T. H. (2010), *Wood Handbook-Wood as an Engineering Material*, Forest Product Laboratory, Forest Service, U.S. Department of Agriculture, Madison.