Buletin Penelitian Hasil Hutan
Vol. 16 No.5 (1999) pp. 279 – 286

THE PROPERTIES OF CEMENT-BONDED BOARDS FROM SENGON WOOD *

(*Sifat papan semen dari kayu sengon*)

By/*Oleh*

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Ringkasan

Papan semen skala laboratorium dibuat dari serutan kayu sengon (Paraserianthes falcataria (L) Nielsen) dengan perbandingan berat antara kayu dan semen 1:2,5. Magnesium khlorida ($MgCl_2$) dan natrium silikat (Na_2SiO_3) digunakan sebagai katalisator. Banyaknya $MgCl_2$ atau Na_2SiO_3 yang ditambahkan pada saat pembuatan papan semen adalah 0; 2,5; 5; 7,5 dan 10 % dari berat semen.

Kerapatan rata-rata papan semen yang dibuat adalah 1,17 g/cm^3. Macam dan banyaknya katalisator berpengaruh nyata pada sifat fisis dan mekanis papan semen kecuali pada sifat pengembangan linier. Penambahan $MgCl_2$ terutama 5% memperbaiki sifat papan semen, tetapi tidak ada pengaruh yang nyata pada perlakuan lain. Modulus patah papan semen yang dibuat dengan katalisator $MgCl_2$ (118-133 kg/cm^2) memenuhi persyaratan BISON dan ISO (90-150 kg/cm^2). Keteguhan rekat internal dari papan semen tersebut lebih baik dari pada papan semen yang dibuat dengan katalisator Na_2SiO_3. Berdasarkan hasil penelitian ini, disarankan untuk menambahkan $MgCl_2$ sebanyak 5 % dari berat semen dalam pembuatan papan semen.

Kata kunci : papan semen, kayu sengon, $MgCl_2$, Na_2SiO_3.

Summary

*Laboratory scale cement-bonded boards were made from shavings of sengon wood (*Paraserianthes falcataria *(L.) Nielsen), with the wood-cement ratio of 1 : 2.5. Magnesium chloride ($MgCl_2$) and sodium silicate (Na_2SiO_3) were used as mineralizers. The amount of magnesium chloride or sodium silicate added during boards fabrication were 0; 2.5; 5; 7.5; and 10% based on cement weight.*

The average density of the boards produced was 1.17 g/cm^3. The type and quantity of mineralizer significantly affected the physical and mechanical properties of the boards except the linear expansion. The addition of $MgCl_2$ particularly at 5%, improved the properties of cement-bonded boards. However, there were no significant results in other treatments. The modulus of rupture of all $MgCl_2$ - mineralized boards (118 - 133 kg/cm^2) could comply with the BISON and International Standard requirements (90 - 150 kg/cm^2). Meanwhile, the $MgCl_2$ - mineralized boards had better internal bond strength and dimensional stability than those of Na_2SiO_3. Based on these results, the addition of 5% $MgCl_2$ based on cement weight during board fabrication is recommended .

Key words: cement-bonded board, sengon wood, $MgCl_2$, Na_2SiO_3.

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* This paper was presented in The Sixth International Inorganic-Bonded Wood & Fiber Composite Materials Conference in Sun Valley, Idaho, USA, September 27-30, 1998.
(Tulisan ini telah diseminarkan dalam The Sixth International Inorganic-Bonded Wood & Fiber Composite Materials Conference di Sun Valley, Idaho, USA, tanggal 27- 30 September 1998)

I. INTRODUCTION

Sengon wood (*Paraserianthes falcataria* (L.) Nielsen) belongs to Mimosaceae family. It is indigenous species which grows in eastern part of Indonesia especially in the islands of Maluku and Irian Jaya. At present, however, this species has been cultivated throughout Indonesia because of its fast growing. Sengon grows on infertile and moderately porous, dry as well as wet or moderately salty soils. Young plants resist shortage of oxygen up to 31.5 days. The species requires humid to moderately dry climate, from lowland plains to mountains up to 1,500 m above sea level.

Sengon wood is used to a large extent by the people of West Java as housing materials (board, beam, column, rafter, etc). Formerly in Maluku sengon wood was commonly used for shields, due to its lightness and toughness as well as its high resistence to piercing (Martawijaya,*et al.*, 1992). Nowadays not only is the utilization of sengon wood for sawn timber but also it has been developed further to produce wood working products (jointed board), plywood, laminated veneer lumber and furniture components. The development of wood working industry which uses sengon wood as its raw materials results in a lot of wood wastes like sawdust and shavings. Until now the utilization of sengon wood waste like shavings is very limited and only for fuel. Therefore, research on the utilization of sengon wood as raw materials for cement-bonded boards was carried out.

II. MATERIALS AND METHODS

A. Preparation of wood particles

Several sengon rafters were collected from Bogor, West Java. The rafters were then manually fed into the planner machine, which resulted in shavings (wood particles). The shavings which were considered as wood waste from planner machine were then collected and passed through the screen (2.5 x 2.5 cm, hole dimension) and used as raw materials for cement-bonded boards. The dimensions of shavings were about 2.5 - 6 cm long, 1.6 - 2.6 cm wide, and 0.55 mm thick.

B. Board manufacture

The experimental design is shown in Table 1. Total number of boards manufactured were : 2 mineralizers x 5 quantity levels of mineralizer x 3 replications = 30.

Experimental cement-bonded boards were prepared by wetting the sengon wood particles (shavings) with the magnesium chloride or sodium silicate solutions. The mineralizer was dissolved in water. Cement was then mixed thoroughly with the wet wood particles. The mixture was then hand-formed into a loose mat in a wooden deckle box (30 x 30 cm internal dimensions). The wooden deckle box was removed and wooden sticks (10 mm thick) were placed on the sides of the mat. The mat was then pressed to thickness and clamped for 20 hours at room temperature. The boards produced were left at room temperature for one month prior to the testing.

Table 1. The experimental conditions for the manufacture of cement-bonded boards
Tabel 1. Kondisi percobaan pembuatan papan semen

Wood - cement ratio (Nisbah berat antara kayu dan semen)	1 : 2.5
$MgCl_2$ or Na_2SiO_3, % based on cement weight ($MgCl_2$ atau Na_2SiO_3, % dari berat semen)	0; 2.5; 5 ; 7.5 ; 10
Wood - water ratio (Nisbah berat antara kayu dan air)	1 : 2
Board size, cm (Ukuran papan,cm)	30 x 30 x 1
Board density target, g/cm³ (Target kerapatan papan, g/cm³)	1.2

C. Testing

The boards were cut into desired specimen dimensions. Each board was cut to yield the specimens required to determine the board properties such as board density, moisture content, thickness swelling, linear expansion, bending strength, internal bond and screw holding power. The tests were performed using American Standard ASTM D 1037 - 93 (Anonymous,1995) with some modifications for evaluating the properties of cement-bonded boards.

A completely randomized design with nested experiment was used in which the type of mineralizer as the nest and the quantity of mineralizer as the treatment factor. Three replications were made for each treatment. If the effect of either the nest or the treatment factors proved significant on the board properties, then further evaluation would be carried out using the honestly significant difference's range test.

III. RESULTS AND DISCUSSION

Sengon wood (*Paraserianthes falcataria* (L.) Nielsen) could be used directly as cement-bonded board's raw materials. The data on physical and machanical properties of the boards are presented in Table 2. Analysis of variance tests were carried out on the data and the results are summarized in Table 3. The density of cement - bonded boards varied from 1.13 g/cm^3 to 1.20 g/cm^3 with an average of 1.17 g/cm^3. The average moisture content of the boards was 10.14 %. BISON (Anonymous, 1975) stated that the maximum density of cement-bonded board is 1.25 g/cm^3 which corresponds to a wood - cement ratio of approximately 1 : 2.75. Lower densities are possible but by reducing the portion of cement. A density of 1 g/cm^3 and a wood -cement ratio of approximately 1 : 1.8 can be accepted. Therefore, it was reasonable that the average density of the boards as produced in this study was (1.17 g/cm^3) lower than that of BISON product (1.25 g/cm^3) because the wood-cement ratio applied in this study was approximately 1: 2.5. The density of all boards, however, could comply with the International Standard (ISO) requirement because the values were not less than 1 g/cm^3 (Anonymous,1987).

The average density of cement-bonded boards mineralized with $MgCl_2$ was 1.18 g/cm^3 while the density of those mineralized with Na_2SiO_3 was 1.16 g/cm^3. It was observed that both the type and quantity of mineralizer had no significant effect on board density (Table 3). This result supports the finding of Sutigno *et al.* (1977) where the type of mineralizer, $CaCl_2$ and $Ca(OH)_2$, did not affect the density of cement-bonded boards of five wood species.

The thickness swelling values were influenced by the type of mineralizer and its quantity (Table 3). The cement-bonded boards mineralized with $MgCl_2$ had an average thickness swelling of 2.73% (2 hours soaking) and 3.80% (24 hours soaking), which were lower than that with Na_2SiO_3 being 4.9 % and 6.70 % after the corresponding 2-hour and 24 -hour soaking respectively. The increase in quantity of mineralizer obviously improved dimensional stability (decreasing thickness swelling value) of the $MgCl_2$ - mineralized boards, but it is not so with Na_2SiO_3. However, the thickness swelling properties did not comply with both BISON and International Standard requirements. The possible reason was the wood-cement ratio as applied in this investigation was 1 : 2.5 whereas in BISON product the ratio was 1 : 2.75.

Table 2. Physical and mechanical properties of cement-bonded boards
Tabel 2. Sifat fisis dan mekanis papan semen

No	Properties (*Sifat*)		Quantity of mineralizer (I and II) (*Banyaknya katalisator*), %				
			0	2.5	5	7.5	10
1	Moisture content (*Kadar air*), %	I II	7.34 7.34	9.23 9.41	10.60 10.68	11.13 10.62	11.83 13.23
2	Density (*Kerapatan*), g/cm³	I II	1.17 1.17	1.19 1.20	1.19 1.17	1.18 1.13	1.19 1.13
3	Thickness swelling (*Pengembangan tebal*), %						
	a. 2 hours (*2 jam*)	I II	3.75 3.75	3.23 4.26	2.15 3.80	2.19 5.97	2.33 6.36
	b. 24 hours (*24 jam*)	I II	6.35 6.35	3.92 5.15	3.14 4.85	2.91 8.61	2.70 8.56
4	Linear expansion (*Pengembangan linier*), %						
	a. 2 hours (*2 jam*)	I II	0.20 0.20	0.20 0.17	0.17 0.15	0.17 0.15	0.20 0.17
	b. 24 hours (*24 jam*)	I II	0.26 0.26	0.23 0.18	0.18 0.16	0.20 0.23	0.23 0.20
5	MOR (*Modulus patah*), kg/cm²	I II	89.48 89.48	117.74 86.75	133 78.73	127.38 57.55	128.96 42.60
6	MOE (*Modulus elastisitas*), x 10³ kg/cm²	I II	20.39 20.39	27.29 20.40	30.25 18.22	26.02 12.67	24.38 7.59
7	Internal bond (*Keteguhan rekat internal*), kg/cm²	I II	1.28 1.28	3.17 2.69	3.35 2.87	3.20 1.96	3.74 0.96
8	Screw holding power (*Kuat pegang sekrup*), kg/cm²	I II	88 88	176 157	182 117	151 105	150 63

Remarks (*Keterangan*) I = $MgCl_2$, II = Na_2SiO_3

Table 3. Summarized results of analysis of variance on physical and mechanical properties of cement-bonded boards

Tabel 3. Ringkasan sidik ragam sifat fisis dan mekanis papan semen

No	Properties (*Sifat*)	F calculated (F hitung)	
		Type of mineralizer (*Jenis katalisator*)	Quantity of mineralizer within type (*Banyaknya katalisator dalam jenis*)
1	Density (*Kerapatan*)	ns	ns
2	Thickness swelling (*Pengembangan tebal*)		
	a. 2 hours (*2 jam*)	**	**
	b. 24 hours (*24 jam*)	*	**
3	Linear expansion (*Pengembangan linier*)		
	a. 2 hours (*2 jam*)	ns	ns
	b. 24 hours (*24 jam*)	ns	ns
4	MOR (*Modulus patah*)	**	**
5	MOE (*Modulus elastisitas*)	*	**
6	Internal bond (*Keteguhan rekat internal*)	ns	**
7	Screw holding power (*Kuat pegang sekrup*)	*	**

Remarks (Keterangan) : ns = not significant (tidak nyata)
* = significant (nyata)
** = highly significant (sangat nyata)

The type and quantity of mineralizer did not affect the linear expansion (Table 3). The $MgCl_2$ - mineralized boards had an average linear expansion of 0.19 % (2 hours soaking) and 0.22 % (24 hours soaking), while those with Na_2SiO_3 were 0.17% (2 hours soaking) and 0.21 % (24 hours soaking). The linear expansion of all boards produced complied with the BISON requirements.

Both MOR and MOE values were influenced by both the type and quantity of mineralizer (Table 3). The average MOR and MOE values of the boards produced with $MgCl_2$ were respectively 119.24 kg/cm^2 and 25,666 kg/cm^2 , higher than the corresponding values with Na_2SiO_3 which were 71.02 kg/cm^2 and 15,854 kg/cm^2 consecutively. The average MOR and MOE values of the control board were 89.48 kg/cm^2 and 20,390 kg/cm^2 respectively. The addition of $MgCl_2$ during board fabrication tends to increase the MOR and MOE of the boards. Nevertheless, the increase in $MgCl_2$ level was not always followed by the increase in MOR and MOE values. On the other hand, the addition of Na_2SiO_3 during board fabrication did not improve the MOR and MOE of the boards. It was observed that the MOR value decreased with the increase in quantity of Na_2SiO_3. This trend, however, was not clear on the performance of MOE.The previous study on wood-wool board from 73 wood species showed that the type of mineralizer, $CaCl_2$ and $Ca(OH)_2$, affected the bending strength of wood-wool board. The boards mineralized with $CaCl_2$ had better bending strength than those with $Ca(OH)_2$ (Sutigno and Sulastiningsih,1986).

Table 4. Test of significant difference of the effect of quantity of mineralizer on cement-bonded board properties

Tabel 4. Uji beda pengaruh banyaknya katalisator terhadap sifat papan semen

No.	Properties (*Sifat*)		Mean value comparison, P (*Perbandingan nilai rata-rata*)				
1.	Thickness swelling (*Pengembangan tebal*, %)						
	a. 2 hours (*2 jam*) D 0.01 = 2.07%	I	P3 2.15	P4 2.19	P5 2.33	P2 3.23	P1 3.75
		II	P1 3.75	P2 3.80	P3 4.62	P4 5.97	P5 6.36
	b. 24 hours (24 jam) D 0.01 = 2.11%	I	P5 2.70	P4 2.91	P3 3.14	P2 3.92	P1 6.35
		II	P3 4.85	P2 5.15	P1 6.35	P5 8.56	P4 8.61
2	MOR (Modulus patah), kg/cm^2 D 0.01 = 26.24 kg/cm^2	I	P1 89.48	P2 117.74	P4 127.38	P5 128.96	P3 132.64
		II	P5 42.60	P4 57.55	P3 78.73	P2 86.75	P1 89.48
3.	MOE (Modulus elastisitas), x 10^3 kg/cm^2 D 0.01 = 9.7 x 10^3	I	P1 20.39	P5 24.38	P4 26.02	P2 27.29	P3 30.25
		II	P5 7.59	P4 12.67	P3 18.22	P1 20.39	P2 20.40
4	Internal bond (Keteguhan rekat internal), kg/cm^2 D 0.01 = 1.43	I	P1 1.28	P2 3.17	P3 3.20	P4 3.35	P5 3.74
		II	P5 0.96	P1 1.28	P4 1.96	P2 2.69	P3 2.87
5.	Screw holding power (Kuat pegang sekrup), kg/cm^2 D 0.01 = 39.63	I	P1 88	P4 151	P5 150	P2 176	P3 182
		II	P5 64	P1 88	P4 105	P3 117	P2 157

Remarks (*Keterangan*) :

I = $MgCl_2$; II = Na_2SiO_3

P = Quantity of mineralizer (% of cement weight) / *Banyaknya katalisator (% dari berat semen)*

P1 = 0% ; P2 = 2.5% ; P3 = 5% ; P4 = 7.5% ; P5 = 10%

—— = Not significant difference (*Tidak berbeda nyata*)

The MOR of all boards produced with $MgCl_2$, (118 - 133 kg/cm^2) met with the BISON and International Standard requirements. In contrast, the MOR of all boards produced with Na_2SiO_3 (57 - 89 kg/cm^2) did not meet with the requirements. The boards produced with the addition of 5% $MgCl_2$ of cement weight met with the minimum MOE requirements of BISON and International Standards.

Both the internal bond strength (IB) and screw holding power (SH) values of the boards were greatly affected by the quantity of mineralizer. It was observed, however, that the increase in mineralizer quantity was not always followed by the increase in IB and SH values. There is no significant difference in both IB and SH values of boards resulted in the addition of $MgCl_2$ at 2.5 %, 5 %, 7.5 % and 10 % on cement weight. On the other hand, the effect of Na_2SiO_3 level on both IB and SH values were more varied. The average of IB and SH values of the boards produced with $MgCl_2$ were 3.37 kg/cm^2 and 165 kg/cm^2, respectively, while those produced with Na_2SiO_3 were 2.12 kg/cm^2 and 110 kg/cm^2 consecutively. The average IB and SH values of the control board were respectively 1.28 kg/cm^2 and 88 kg/cm^2. The IB values of all boards produced, with the values of 0.96 - 3.74 kg/cm^2, did not meet with the BISON requirements (4 - 6 kg/cm^2). Conversely, the SH values of all boards produced with $MgCl_2$ at all levels and those with Na_2SiO_3 up to 7.5 % met with the BISON requirements (minimum 90 kg/cm^2). In the International Standard the IB and SH values are not specified.

IV. CONCLUSIONS

The average density of cement-bonded boards made from sengon wood were 1.17 g/cm^3 and it was not affected by both the type and quantity of mineralizer.

The type and quantity of mineralizer had significant effect on the physical and mechanical properties of the boards except the density and linear expansion. In general, the utilization of $MgCl_2$ as mineralizer produced better board properties than that of Na_2SiO_3.

The cement-bonded boards produced with $MgCl_2$ at 5 % level resulted in the board properties which could meet the BISON and International Standard requirements except the internal bond strength.

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