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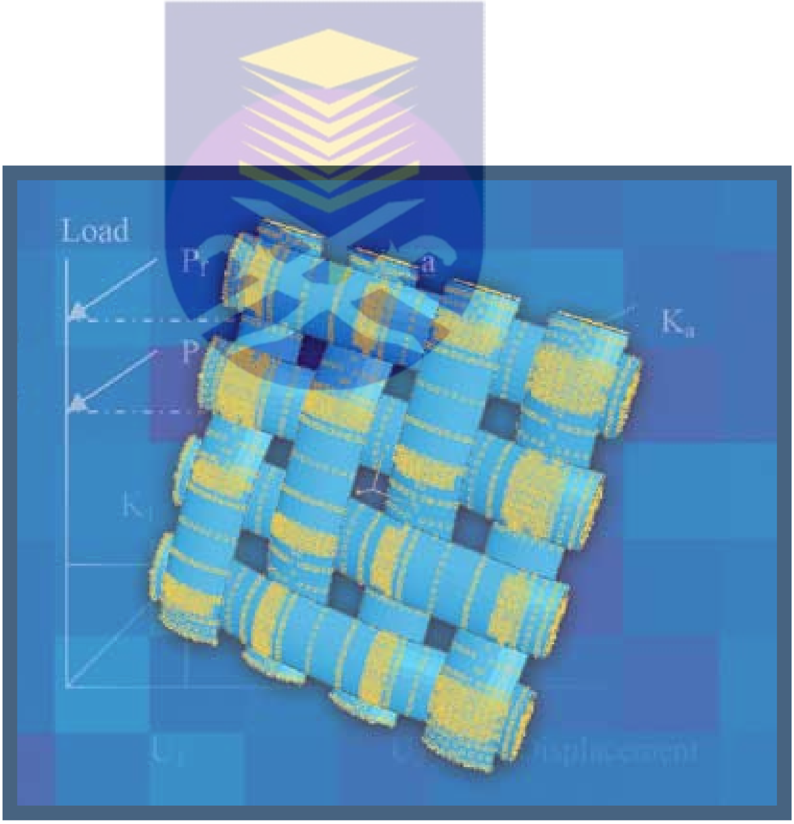

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Effects of Particle Sizes, Wood to Cement Ratio and Chemical Additives on the Properties of Sesendok (*Endospermum Diadenum*) Cement-bonded Particleboard

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ABSTRACT

An experimental investigation was performed to evaluate the properties of cement-bonded particleboard made from Sesendok wood. The target board density was set at a standard 1200 kg m^{-3}. The effect of particle size, wood to cement ratio and the addition of sodium silicate and aluminium silicate on the wood cement board properties has been evaluated. A change of particle size from 1.0 mm to 2.0 mm has a significant effect on the mechanical properties, however the physical properties deteriorate. Increasing the wood to cement ratio from 1:2.25 to 1:3 decreases the modulus of rupture (MOR) by 11% and the addition of sodium silicate improves values further by about 28% compared to the addition of aluminum silicate. The modulus of elasticity (MOE) in general increases with increasing cement content, but is not significantly affected by the addition of sodium silicate or aluminium silicate, although the addition of their mixture (sodium silicate and aluminium silicate) consistently yields greater MOE values. Water absorption and thickness swelling is significantly affected by the inclusion of additives and better values are attained using higher wood to cement ratios.

***Keywords**: Sesendok, particle sizes, wood to cement ratio, additives, cement-bonded particleboard.*

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Introduction

Panels composed of particles or wood fibers held together by a Portland cement matrix are gradually gaining importance in a number of countries around the world in interior and exterior structural and construction applications [1]. The increased importance of these wood cement composites is due their inherent properties; strong, stiff, and resistant to moisture, fire, fungi and insects. In addition to the construction of flat panels, the same basic concept can be used to produce other products such as bricks, blocks and roof tiles.

Wood cement bonded particleboard was first introduced in Malaysia by CEMBOARD in 1982 [2] and primarily uses rubber wood as a raw material in its production. The supply of rubber wood will dwindle and ultimately will be unable to satisfy the future demands of the cement board industry. Consequently, new wood sources will be required to address this shortfall in rubber wood. The objectives of this research are to study the suitability of *Endospermum Diadenum* as an alternative wood source in cement board manufacture and the effect of particle size, wood to cement ratio and the addition of chemical additives; namely sodium silicate and aluminium silicate, on board properties.

Materials and Methods

Material Preparation

Three Sesendok trees were acquired from the UiTM Pahang forest reserve. The trees had an average diameter greater than 20 cm at breast height. The logs were debarked and cut lengthwise by a resaw to produce lumber measuring 1 inch × 1 inch × 8 feet. Chipping produced wood chips which were then fed into a Knife Ring Flaker to reduce them into particles. The particles were air-dried before screening produced particles of 1 and 2 mm in diameter.

Cement Board Manufacturing

The particles, with a moisture content of about 45%, were fed into a mixer and homogeneously combined with cement, sodium silicate (Na_2SiO_3)(1.5%) and/or aluminium silicate ($Al_2(SiO_4)_2$) (3.0%) and water. The ratios of wood to cement used in this investigation were 1:2.25, 1:2.5 and 1:3. The resultant particles were mat formed into cement boards and a cold press was then employed to reduce the mat thickness. The target board density was set at a standard 1300 kg m^{-3}.The mats were then stacked in a clamp carriage and compressed to the required thickness of 10 mm. The whole carriage was then placed in a hardening chamber and the mats left to harden for 24 hours. The cement-bonded particleboards were then removed, stored and conditioned at room temperature for two weeks in order to ensure that they had fully hardened.

Board Evaluation

The conditioned boards were cut into specific dimensions to enable evaluation of their mechanical and physical properties: modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding (IB), water absorption (WA) and thickness swelling (TS). All tests were conducted in accordance with the Malaysian MS 934 (1986) standard [3].

Results and Discussion

Properties of Cement-Bonded Particleboard

The properties of Sesendok Cement-Bonded Particleboard (CBP) are presented in Table 1. The highest MOR recorded was for the boards manufactured using 1 mm particles, a wood to cement ratio of 1:2.5 and with the addition of sodium silicate. The highest MOE recorded was for the CBPs using 1 mm particles, a wood to cement ratio of 1:3 and with the addition of both sodium and aluminium silicates. The lowest thickness swelling was exhibited by the CBPs made using 2 mm particles, a wood to cement ratio of 1:2.5 and with the addition of aluminium silicate. All CBPs manufactured using 1 mm particles, a wood to cement ratio of 1:2.25 and with the addition of either silicate, but not both, meet the requirements for the MS 934 standard [3].

Table 1: Properties of Wood Cement Board According to Particle Size, Wood to Cement Ratio and Chemical Additive

PARTICLE SIZE	WOOD RATIO	ADDITIVES	MOR	MOE	IB	WA	TS
2.0	1:2.25	AL	9.40	2710.45	0.45	17.20	1.93
		NA	11.76	2298.40	0.50	16.45	3.76
		MIX	12.34	3258.11	0.11	13.77	1.85
	1:2.5	AL	6.40	1751.87	0.31	20.00	0.96
		NA	9.28	2586.27	0.31	21.11	1.50
		MIX	12.01	3236.34	0.51	10.89	2.42
	1:3.0	AL	7.50	2491.32	0.12	18.34	1.40
		NA	9.63	1896.03	0.47	13.39	2.98
		MIX	10.64	3403.45	0.63	15.43	2.02
1.0	1:2.25	AL	9.49	2623.24	0.68	15.91	1.64
		NA	12.17	3022.64	0.56	11.96	1.46
		MIX	11.18	2830.00	0.88	15.60	2.02
	1:2.5	AL	9.19	2920.09	0.41	15.71	2.16
		NA	12.49	3650.96	0.72	11.95	1.13
		MIX	12.17	3715.37	0.42	9.74	1.51
	1:3.0	AL	9.07	3205.01	0.26	11.87	1.09
		NA	10.20	3099.11	0.88	11.82	1.08
		MIX	11.82	4132.44	0.47	7.81	1.88
MS 934	1986		>9.00		>0.50		<2.00

Notes: AL - Aluminium silicate, NA - Sodium silicate, MIX - Mixture of AL and NA.

Statistical Significance

Table 2 presents the ANOVA for the board properties with respect to particle size (PS), wood to cement ratio (W:C) and additives (ADD). The relatively high ANOVA values for PS, W:C and ADD indicate that they have a significant effect on board properties, although combined effects are generally less pronounced. However it is apparent that W:C has little effect on MOE and IB.

Table 2: ANOVA Summary of Board Properties

SOV	DF	MOR	MOE	IB	WA	TS
PS	1	5.60*	13.12*	15.15*	21.20*	8.58*
W:C	2	3.13*	0.99ns	0.85ns	2.36*	2.59*
ADD	2	21.54*	10.02*	4.71*	9.66*	2.52*
PS X WC	2	2.54*	2.59*	1.83ns	2.57*	1.95ns
PS X ADD	2	1.25ns	1.96ns	0.60ns	1.12ns	7.68*
WC X ADD	4	0.99ns	2.28*	2.94*	2.26*	1.92ns
PS X WC X ADD	4	0.57ns	0.26ns	5.05*	2.67*	2.45*

Notes: SOV - Source of variance, DF - Degrees of freedom, PS - Particle size, WC - Wood to cement ratio, ADD - Additives, * - Significance and ns - No significance.

Effect of Particle Size (PS)

The affect of PS on the mechanical and physical properties are presented in Figures 1 and 2, respectively. A change in PS from 1 mm to 2 mm significantly affects the mechanical properties: whereby the MOR and MOE decrease by 9% and 18%, respectively. The decrease in mechanical properties with increasing PS is due to increased cement bonding with the wood particles through encapsulation, which ensures continuity within the cement matrix.

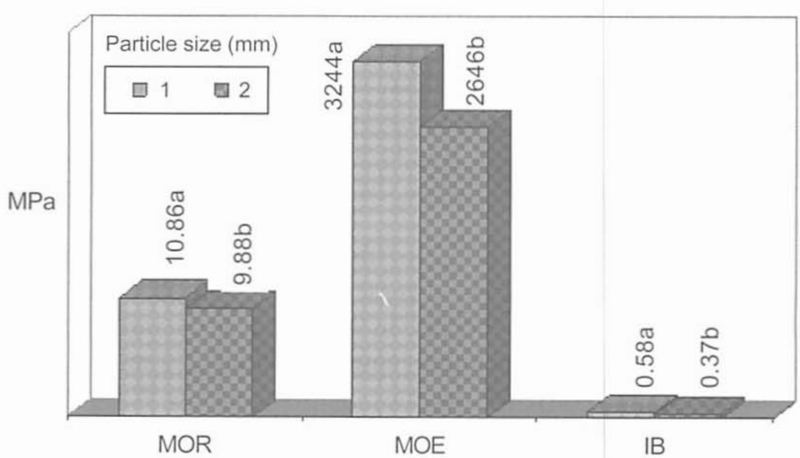

Figure 1: Effect of Particle Size on Mechanical Properties

The WA and TS are also significantly affected by the PS. Increasing the PS causes the WA and TS to increase by 30% and 35%, respectively. Higher WA and TS values are a consequence of larger PS, which causes incomplete coverage of the particle surfaces, *i.e.* reduced protection and insulation, thus enabling absorption of higher volumes of water.

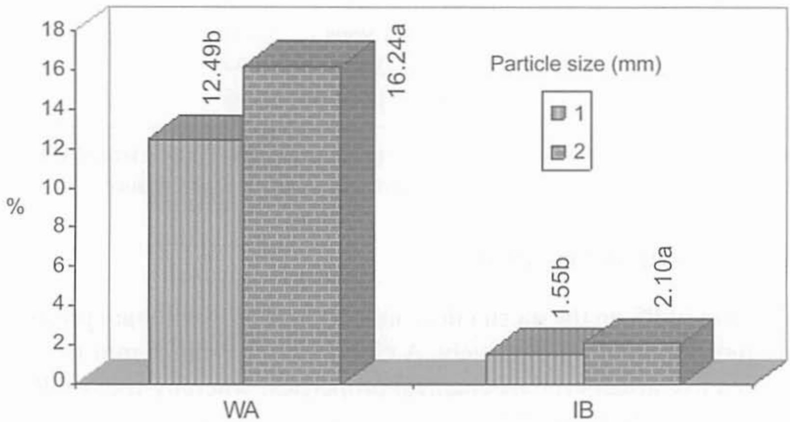

Figure 2: Effect of Particle Size on Physical Properties

Effect of Wood: Cement Ratio

Figures 3 and 4 present the effects of the wood to cement ratio (W:C) on the mechanical and physical properties, respectively. Increasing the cement content from 2.25 to 3 decreases the MOR by 11%, but the MOE increases marginally. This decrease in the MOR may be attributed to the production of a more fragile wood cement-board structure, whereas the higher MOE is due to the greater proportion of cement used [4].

Figure 4 presents the effect of the W:C ratio on the physical properties of the Sesendok wood cement-board. The WA and TS are significantly affected by an increase in W:C ratio; as the ratio increases from 1:2.25 to 1:3 there is an improvement of about 13% and 17.5% for WA and TS, respectively. WA decreases with increasing W:C ratio due to fewer wood particles exposed to the cement and therefore less water is absorbed and swelling decreases, which is in accordance with the work of Marzuki *et al.* [5].

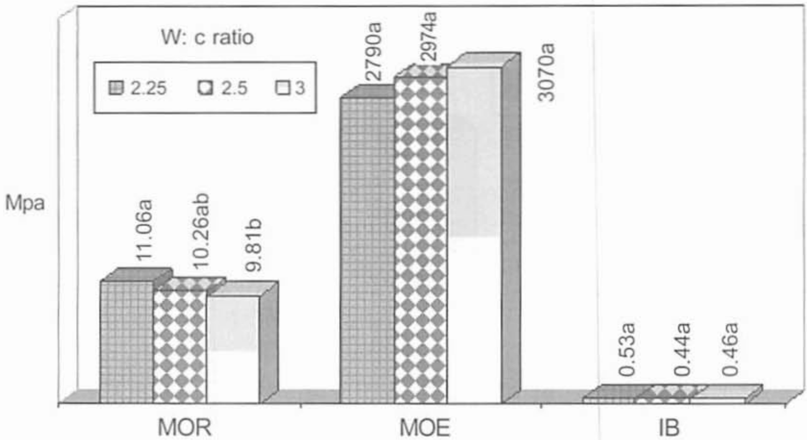

Figure 3: Effect of W:C Ratio on Mechanical Properties

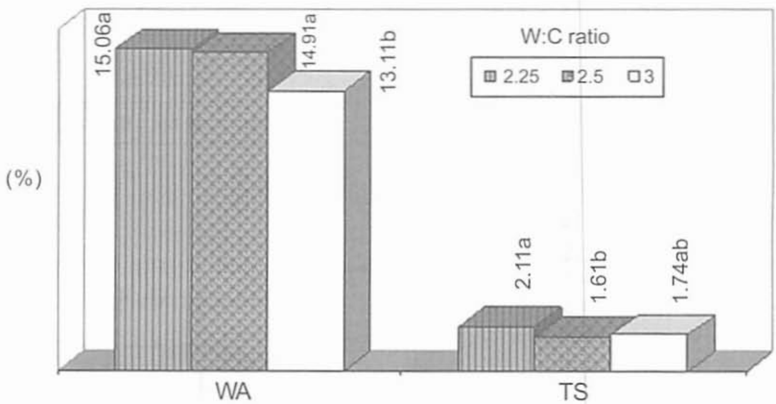

Figure 4: Effect of W:C Ratio on Physical Properties

Effects of Chemical Additives

The affect of additives on the mechanical and physical properties are presented in Figures 5 and 6, respectively. The additives have been found to significantly influence MOR values as reported by Rahim *et al.* [6]. The addition of sodium silicate (NA) consistently yields better MOR and MOE values than aluminium silicate and the addition of their mixture further increases MOR values. Figure 6 clearly indicates that WA and TS are significantly affected by the presence of the additives, but that the mixture has less affect than pure sodium silicate.

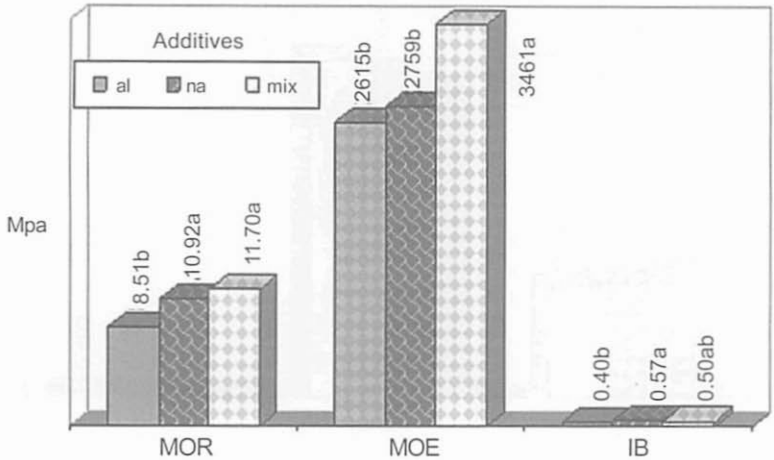

Figure 5: Effect of Additives on Mechanical Properties

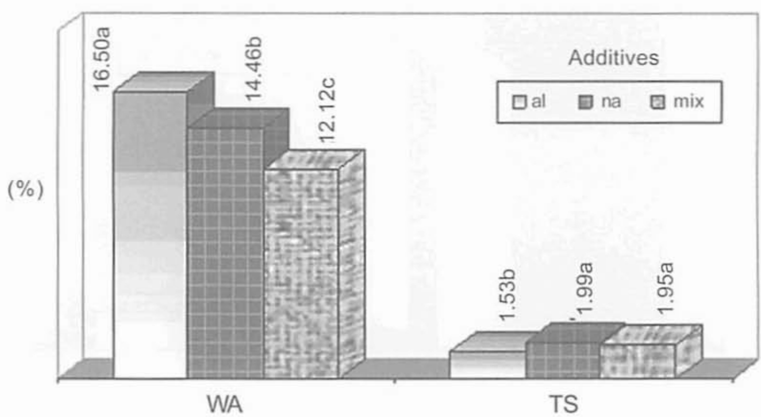

Figure 6: Effect of Additives on Physical Properties

Conclusions

Particle size, wood to cement ratio and the presence of additives with respect to the ANOVA results all affect the mechanical and physical properties of the Serendok CBPs. Changing the particle size from 1 mm to 2 mm decreases the MOR and MOE values, but increases the WA and TS values. Higher cement content causes a general decrease in MOR, WA and TS values, but MOE values tend to increase. The addition of sodium silicate yields better MOR values compared to aluminum silicate, but their mixture further increases the MOR and MOE values.

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