EFFECT OF WOOD/GYPSUM RATIO AND DENSITY ON STRENGTH PROPERTIES OF GYPSUM-BONDED PARTICLEBOARD FROM OIL PALM STEMS

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RAHIM SUDIN & KHOZIRAH SHAARI. 1991. Effect of wood/gypsum ratio and density on strength properties of gypsum-bonded particleboard from oil palm stems. Three-layer gypsum-bonded particleboards were prepared from oil palm stems and tested for their strength properties. Three wood:gypsum ratios (1:2.5, 1:3.0 and 1:3.5) were used and board density was varied between 1000 to 1300 $kg\ m^{-3}$. The oil palm particles were not given any pretreatment and no chemical retarders were added in the wood:gypsum mixture. Boards with minimum density of 1150 $kg\ m^{-3}$ and wood:gypsum ratios of 1:2.5 had strength properties which were comparable to those of commercial gypsum-bonded particleboards. The strength properties of gypsum-bonded particleboard were generally improved with the increase of density and gypsum to wood ratio. The highest MOR value (9.28 *MPa*) and internal bond (0.78 *MPa*) were obtained from gypsum-bonded particleboard manufactured at gypsum/wood ratio of 3.5:1 and density 1300 $kg\ m^{-3}$.

Key words: Oil palm stems - gypsum-bonded particleboard - wood/gypsum ratio - density - strength properties

Introduction

Gypsum is an inorganic binder that is widely used for interior building, usually in the form of gypsum plasterboards. Incorporation of organic fibrous materials such as wood or fibreglass into the gypsum matrix is known to improve the brittle-fracture resistance and strength properties of the gypsumboards, thus giving more versatility to the finished product (Sattler & Lempfer 1989).

The introduction of gypsumboard reinforced with wood particles into the world market is fairly recent. The first industrial plant was installed in Finland, using local timber species and 100% waste gypsum from a phosphoric acid plant as raw materials (Schwarz 1986). The choice of wood material depends largely on its compatibility with gypsum and the suitability of most softwoods and hardwoods has already been established (Simatupang & Lu 1985). Other ligno-cellulosic materials from agricultural wastes, such as oil palm stems, can be a possible alternative to the depleting supply of wood.

In Malaysia, oil palm stems are generated in great abundance during replanting programmes. The amount of oil palm stems available in 1990 alone has been estimated to be in the region of 3.6 million m^3 and by the year 1998, this amount is expected to reach 20.4 million m^3 (Mohd Husin *et al.* 1986). In this paper, the suitability of oil palm stem as the reinforcing material for the manufacture of experimental gypsum-bonded particleboard is evaluated.

Materials and methods

Oil palm stems

Three 23-y-old oil palm trees of the *Dura* x *Pisifera* variety were taken from the nearby KL-Kepong Estate in Selangor. Each tree was felled 1.5 *m* above the ground and subsequently cut into billets of 2 *m* length before being transported to FRIM. Each billet was split-cut into planks of 3.5 to 5 *cm* thick and then processed into flakes through chipping and flaking with the Pallmann drum-chipper and Pallmann knife-ring flaker respectively. The oil palm flakes were further oven dried at 80°*C* for about two days and screened into fine and coarse particles by passing through a 2.0 to 0.5 *mm* mesh sieve. The drying process was necessary to facilitate screening and to avoid fungal growth on the material.

Hydration tests

A series of hydration tests to assess the compatibility of oil palm stem with gypsum was carried out on the following mixtures:

a) gypsum : water (distilled)
b) gypsum : water : dried oil palm particles
c) gypsum : cold water extract
d) gypsum : hot water extract
e) gypsum : water : cold water extracted oil palm particles
f) gypsum : water : hot water extracted oil palm particles

The mixing ratios were 300 *g*: 150 *ml*: 10 *g* for mixtures b), e) and f) and 300 *g*: 150 *ml* for mixtures a), c) and d). These ratios were based on the optimum water to gypsum ratio determined by Simatupang and Lu (1985). Each mixture was thoroughly kneaded in polyethylene bags before the insertion of a 'Type J' thermocouple and transfering into Dewar flasks for temperature measurements. The heat generated from each reaction was recorded on a Shinko Temperature Recorder.

Board manufacture

Three-layer boards were made using particles retained at 0.5 and 1.0 *mm* sieves, as surface and core materials, respectively. Nine series of gypsum-bonded particleboard (GBP) with dimensions 450 × 450 × 10 *mm*, were produced at varying wood:gypsum ratios (1:2.5, 1:3.0 and 1:3.5) and board densities (1000, 1150 and 1300 $kg\ m^{-3}$). The amount of water added was maintained at 30% of overall weight, and no chemical additives were added. Thai gypsum casting plaster conforming to TIS 188:1984 was used as the binder throughout the study. The boardmaking process was carried out according to the 'semi-dry' method outlined in Figure 1. Five pieces of boards were produced from each series. The mechanical and physical properties of these boards were tested according to Malaysian Standard MS 934.

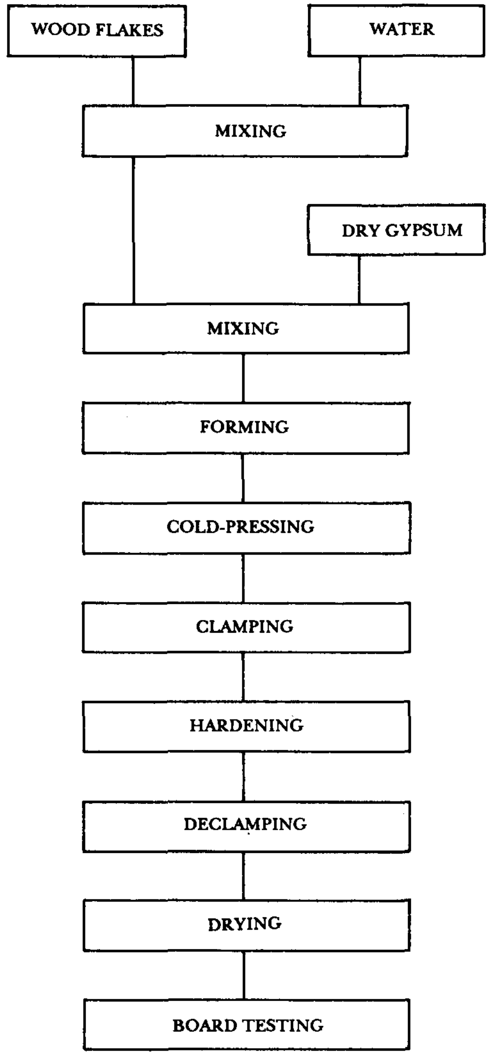
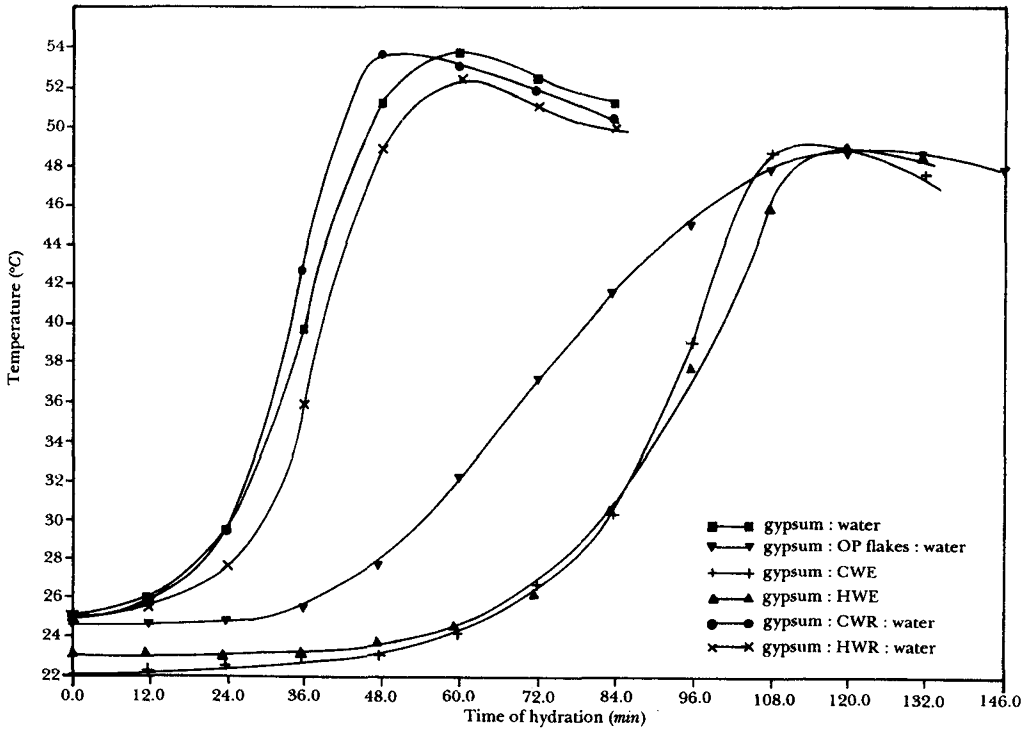


Figure 1. Preparation of "semi-dry" gypsum-bonded particleboard

Results and discussion

Figure 2 shows the heat of hydration curves for the various mixtures of gypsum and oil palm particles and the OPT water extracts. Neat gypsum (mixture a) hydrates very fast, requiring only about 60 *min* to reach its maximum temperature. The incorporation of oil palm particles into the gypsum-water matrix (mixture b) delayed the gypsum setting to almost 120 *min.* This delaying effect was caused by the water soluble components of the oil palm stem as shown by the similar hydration times attained by adding either the cold or hot water extracts of oil palm stem to the gypsum-water matrix (mixtures c and d). On the other hand, the hydration curves for mixtures containing residues of either the cold and hot water extraction (mixtures e and f) were almost identical to that of neat gypsum. According to Simatupang and Lu (1985), polyhydric compounds, especially hydrolyzable tannins and amino acids, are responsible for the retarding effect on gypsum setting.



OP - oil palm CWE - cold water extract HWE - hot water extract HWR - hot water residue CWR - cold water residue

Figure 2. Hydration curves of gypsum with the incorporation of oil palm stem particles and water extracts

In the manufacture of GBP, it is important to ensure that there is ample time for the board-making process to take place before the gypsum matrix reaches the hardening stage (Sattler & Lempfer 1989). Basically, the mixing, spreading and pressing processes should be completed before the mixtures of gypsum-wood-water system reach the maximum hydration temperature. The addition of chemical retarders to delay gypsum setting is a common practice. In the case of oil palm stem the retardation effect caused by its water soluble components may well prove to be of some advantage in the manufacture of GBP in that these components can act as natural retarders and the oil palm stem need not be pretreated prior to use. Therefore, the addition of any chemical retarders may not be necessary in manufacturing GBP from oil palm stems.

The physical and mechanical properties of the nine series of GBP produced are given in Table 1. The results show that the bending strength of GBP produced at density below 1000 $kg\ m^{-3}$ in all ranges of wood/gypsum ratios was below the minimum bending strength of commercial GBP. However, its internal bond and thickness swelling properties were within the allowable range. For the GBP produced at densities above the minimum density of 1150 *kg* m^3 and wood/gypsum ratio of at least 1 : 2.5, all the physical and mechanical properties of the boards were found to be comparable to those of commercial GBP.

Table 1. Physical and mechanical properties of gypsum-bonded particleboards from oil palm stems

Board density (*kg* m^3)	Wood to gypsum ratio	Bending strength (*MPa*) n=20	Internal bond (*MPa*) n=40	Water absorption (%) n=20	Thickness swelling (%) n=20
1000	1 : 2.5	4.71 (1.17)	0.44 (0.14)	26.91 (3.83)	1.20 (1.13)
	1 : 3.0	5.13 (0.78)	0.50 (0.17)	30.79 (6.56)	0.66 (0.37)
	1 : 3.5	5.78 (0.95)	0.58 (0.18)	30.12 (6.18)	0.94 (0.53)
1150	1 : 2.5	7.39 (0.76)	0.55 (0.11)	22.49 (3.40)	2.09 (0.81)
	1 : 3.0	7.64 (0.93)	0.52 (0.13)	16.50 (3.69)	1.46 (0.69)
	1 : 3.5	6.78 (1.13)	0.71 (0.22)	19.30 (1.68)	0.78 (0.50)
1300	1 : 2.5	6.30 (1.06)	0.48 (0.15)	19.70 (2.21)	2.99 (0.90)
	1 : 3.0	8.69 (1.09)	0.57 (0.11)	15.53 (1.63)	1.95 (0.74)
	1 : 3.5	9.28 (0.71)	0.78 (0.23)	12.55 (1.56)	1.28 (0.75)
Commercial GBP properties*	1090 to 1200	6 - 10	0.3-0.6	NA	<2.5

Key: n = no. of testing specimens; figures in parentheses denote standard deviation; NA - data not available; (* Anonymous 1988)

From the strength properties of all boards made, two related trends can be observed (Figure 3). Generally, the mechanical properties of GBP seem to be improved by increasing the board density and also the amount of gypsum added. At the minimum density (1000 *kg* m^3) and minimum wood/gysum ratio (1:2.5), GBP produced gave a bending strength of 4.7 *MPa*. The bending strength was further improved when the density was increased to 1300 *kg* m^3 and wood/gypsum ratio to 1:3.5, reaching a maximum value of 9.28 *MPa*.

Commercially available gypsum-bonded particleboards have bending strength values between 6 to 10 *MPa* (Anonymous 1984). From the results, all gypsum-bonded particleboards made from oil palm stems, produced at densities above 1150 *kg* m^3 and gypsum/wood ratios of 2.5 to 3.5:1, gave physical and mechanical properties comparable to those of commercial GBP.

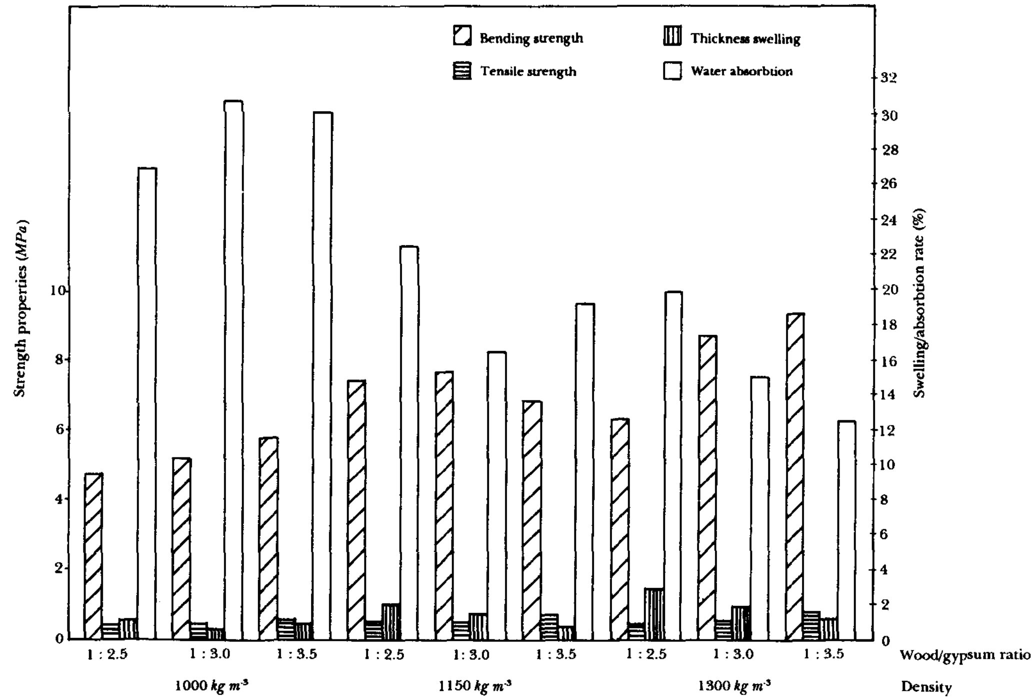


Figure 3. Strength properties of gypsum-bonded particleboard from oil palm stems at various wood/gypsum ratios and density

Conclusion

This study indicates that oil palm stem has the potential to be used as reinforcing material for GBP manufacture. The oil palm stem can be used directly without any pretreatment and no chemical additives are needed because enough retardation of gypsum setting is effected by the extractives present in this material. GBP produced at the minimum density of 1150 $kg\ m^{3}$ and gypsum/wood ratio of 2.5:1 were able to meet the strength requirements of commercial gypsum-bonded particleboards.

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