TRIAL PRODUCTION AND TESTING OF CEMENT-BONDED PARTICLEBOARD FROM RATTAN FURNITURE WASTE

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ABSTRACT

An investigation was conducted on the use of rattan (cane) furniture waste as furnish material for the manufacture of cement-bonded particleboard (CBP). Laboratory scale CBPs were fabricated from hot water pretreated chopped strands of mixed rattan waste obtained from rattan furniture workers in Ibadan, Oyo State, Nigeria. Three-layered boards of 6-mm thickness were made comprising coarse core and fine surfaces at two density levels of 1,050 kg/m^3 and 1,200 kg/m^3, three $CaCl_2$ concentration levels of: 2.5%, 3.0%, and 3.5%, and using Portland cement-cane mixing ratios of 2.5:1.0, 2.75:1.0, 3.0:1.0, and 3.25:1.0. After board manufacture, ASTM D 1037 (1998) test procedures were employed to obtain strength and moisture absorption properties. Average properties for bending modulus of rupture (MOR) and modulus of elasticity (MOE) of the boards ranged between 0.5 and 1.6 N/mm^2, and 480 and 3,563 N/mm^2, respectively. Mean thickness swelling (TS) and water absorption (WA) values ranged between 1.1 and 8.6%, and 31 and 51%, respectively. Analysis of variance showed that except for MOE, the levels at which the density, $CaCl_2$ concentration, and cement-cane mixing ratio were used and their interaction had no significant effects on properties of the board. The relatively low strength and water resistance properties of the boards make them suitable only for use in low-stressed interior applications. Further investigations are, however, required on the effects of different cane preparation procedures and other fabrication variables on board properties. This is necessary to provide the guidelines required to adequately control the fabrication process and optimize material properties.

Keywords: Rattan furniture waste, chemical accelerator, wood-cement particleboard, bending strength, water resistance.

INTRODUCTION

Cement-bonded particleboard (CBP) was developed as an alternative low-cost structural material in the early 1900s (Wolf and Gjinolli 1999). It has since been in use commercially in many parts of the world. Some of its prime areas of utilization in building construction include interior/exterior wall cladding, partitioning, decking, ceiling, roofing, and shuttering (Badejo 1987, 1998; Marcinko et al. 1999; Somayaji 2001). The material has also been used for the full construction of schools, theaters, hospitals, and residential homes in many countries in Africa, North and Central America, and Europe (Badejo 1989; Ramirez-Coretti et al. 1998).

The wide acceptability of CBP products relates to various advantageous properties, such as durability, stability, nailability, relatively light weight, fire resistance, sound attenuation, and ability to provide a nontoxic shield against decay and termites (unlike resin-bonded particleboard). Also, the products lend themselves to modular construction; they satisfy the cultural preference for cement-based construction materials in many parts of the world, particularly in the tropics; and their manufacturing processes usually meet health and safety requirements (Badejo 1989; Shittu 1990; Hsu 1994; Ramirez-Coretti et al. 1998; Wolfe and Gjinolli 1999; Huang and Cooper 2000).

Several lignocellulosic materials have been tested and certified suitable for use in manufacturing CBP over the years. These include sawdust generated from different species of softwoods and hardwoods, building construction waste, peeler cores from veneer and match factories, small size timber, logging wastes, slab wastes from sawmills, recycled treated wood and paper, maize and cotton stalks, and bagasse (Miller and Moslemi 1991; Badejo 1992, Moslemi et al. 1993; Hsu 1994; Oyagade 1994; Badejo 1998; Munson and Kamdem 1998; Ramirez-Corretti et al. 1998). Cement to wood weight mixing ratios of between 1.0:1.0 to 3.0:1.0 have also been reported (Lee and Hong 1987; Badejo 1998; Wolfe and Gjinolli 1999). Many of these lignocellulosic materials, however, contain compounds of soluble sugars and wood extractives. These substances tend to inhibit cement hydration (hardening, setting), thereby inhibiting or entirely obstructing the cement crystallin formation essential to strength development (Weatherwax and Tarkow 1964, 1967; Hofstrand et al. 1984). To minimize these inhibitions to wood-cement bond formation, several physical, chemical, and biological pretreatment methods applicable on the wood furnish have been developed. These pretreatments have made possible the utilization of a wider variety of wood-based materials for CBP production.

Examples of approved pretreatment methods employed on furnish to expedite cement hydration include application of preservatives, prolonged storage, hot water extraction of soluble sugars, and use of chemical additives such as dilute sodium hydroxide (NaOH), sodium silicate (Na_2SiO_3), and calcium chloride ($CaCl_2$) solutions (Lee 1984; Hofstrand et al. 1984; Badejo 1989; Shittu 1990; Oyagade 1994; Shi et al. 1999). It has been suggested that wood particle pretreatments either remove the offending extractives and sugars or make them insoluble, while chemical additives (accelerators) tend to lower the inhibitory effects of wood on setting of Portland cement (Moslemi et al. 1983; Lee and Hong, 1986).

A viable rattan furniture cottage industry is currently flourishing within Ibadan, the capital city of Oyo State, Nigeria. This industry obtains its rattan raw materials, willow cane (*Laccosperma secundiforum*) and brown cane (*Eresmopatha macrocarpa*), from the mangrove forests of Delta State, Nigeria (Isa 1995). The waste generated during furniture manufacturing in the form of cane strands is disposed of by on-site incineration. Preliminary work by Isa (1995) showed that these cane species, in solid form, bond well with cement when used as concrete reinforcement in slabs. Also, Rao and Brij (1968) reported that rattan canes have good elastic properties that can be preserved through proper post-harvest seasoning. However, Dransfield (1988) reported that rattan canes contain starches and sugars that attract bacteria, fungi, and insects in storage. Hence, pretreatment measures against cement bonding inhibition would be required during particleboard manufacturing.

The objective of this work was to fabricate, on the laboratory scale, CBP from pretreated mixed furniture waste derived from willow and brown cane species and to determine the effects of varying cement-cane mixing ratio, calcium chloride concentration level, and board density on the bending strength and sorption properties of these boards.

AN OVERVIEW OF THE PHYSICAL PROPERTIES, PHYTOGEOGRAPHY, AND PROCESSING OF RATTANS

Rattans are spiny, climbing palms belonging to the tropical family *Palmae*. They are monocotyledons, generally found near watercourses. There are approximately 516 species of rattans (IDRC 1979). Although a few species have been cultivated in Indonesia and other Asian countries, the greatest proportion of production comes from plants growing in the natural forests (IDRC 1979; Dransfield 1988; Adefisan 1999). There is wide variation in the stem system of rattans. Some species have solitary stems while others have clustered stems. Some species are even "stemless" (Burkill 1966; IDRC 1979). For species having stem(s), stem diameter also varies considerably. Some *Calamus* spp may be only 3 mm in diameter, whereas the species *Plectocomia elongata* may have 20-cm diameter. Stem diameter hardly increases at all with age, and stem length varies from the very short ones of species such as *C. castaneus* to 200-m stems of *C. manna* and *C. caesius.* Internodal lengths tend to vary considerably within species, among stems from the same clump or even on the same stem (Burkill 1966). Surface features such as color, gloss, and texture also vary considerably among different species of rattan. The outer portion of the stem is usually hard, given the deposit of silica, compared to the inner softer portion known as pith.

The largest genus of rattans is *Calamus* (IDRC 1979). It is widely distributed from West Africa to Fiji and from South China to Queensland. In West Africa, four small genera, *Eremosphatha, Ancistropyllum, Oncocalamus,* and *Laccosperma* are found along with the widespread genus *Calamus* (Dransfield 1974; IDRC 1979; Adefisan 1999). Moore (1973) regarded the three West African genera, *Eremosphatha, Ancistropyllum,* and *Oncocalamus* as showing the greatest number of primitive features within the rattans. Table 1 shows the general features of the four genera of rattans found in Nigeria, West Africa.

TABLE 1. *Physical dimensions of Rattan genera found in Nigeria.*

Species	Diameter Range (mm)	Length of Aerial Stem (mm)
Eresmophata macrocarpa	10–17	20–25
Calamus dearatus	9–12	5–7
Oncocalamus wrighmus	5–10	2–6
Laccosperma secundiform	10–20	10

Source: Adefisan 1999.

Rattan processing generally involves collection/harvesting and conversion into various end uses. Collection is usually by villagers living near the forests. Selection of the rattan to be collected is usually based on the species and age. Collection methods vary slightly from place to place, but in most cases they involve manual handling. The stem is cut 30 to 200 cm above the ground using a cleaver or long chopper; the uppermost 3-to 4-m portion, depending on the species, is usually discarded because of its softness and immaturity, while the rest of the stem is cut into different lengths, depending on factors such as the species, the size of the rattan, the intended form of utilization, buyer's specification, mode of transportation, and the convenience of collectors (IDRC 1979; Adeko 2000). The range of cutting lengths also varies according to the practice in different countries (IDRC 1979). In Nigeria, an average rattan cutting length of 4 m was reported by Adeko (2000).

The major economic uses of rattans are as raw materials for basketry, mat making, binding, weaving, sporting goods, and furniture making. Dried rattan canes processed into skin and core materials are usually used. To produce the rattan skin, the outer 1-to 2-mm portion of the cane is pared off with a knife in even strips running the whole length of the stem. Coring is done either manually or with a machine, and the core is used for basketry or furniture production. The waste produced during splitting and coring, known as "rattan wool" is seldom used, except in countries like Singapore and Hong Kong, where it is sometimes used as stuffing in furniture production (IDRC 1979; Adefisan 1999; Adeko 2000).

Pre-conversion operations conducted on rattans vary from one country to another and also depend on the end uses. Practices adopted in Indonesia include steeping in water to facilitate deglazing, sun-drying to moisture content of approximately 5 to 10%, fumigation with sulfur dioxide (SO_2), steeping a mixture of coconut oil and diesel at 150°C for 30 to 45 min (IDRC 1979). If canes are not dried sufficiently quickly, they are liable to attack by staining and decay fungi, which tend to lower their quality (IDRC 1979). In Nigeria, the major use of rattan is for furniture manufacturing, and only the water steeping and sun-drying methods are practiced.

MATERIALS AND METHODS

Cane furnish processing

Mixed strands of willow and brown cane species collected from a rattan furniture workshop in Ibadan, Oyo State, Nigeria, were reduced to particles by shearing manually with the aid of a hand shear, and sieved. The particles to be used for the two faces were separated from those meant for the core. The average particle length, width, and thickness for the face and core furnish were 30 mm, 5 mm, and 3 mm, and 40 mm, 5 mm, and 3 mm, respectively. Adefisan (1999) had reported the presence of anthraquinones, cardiac glycoside, sterols, and reducing sugars in mixed rattan waste from furniture workshops in Ibadan. To reduce the inhibitive effects of these substances on cement setting and hardening, the particles were soaked for 30 min in hot water at a temperature of 80°C. They were then drained, rewashed with cold water, and air-dried to average moisture content of 12% over a period of 10 days.

Board fabrication

Type I commercial Portland cement was used as a binder for the study. It was purchased locally from cement dealers in the standard paper bag size of 50 kg, and stored in sealed plastic bags to avoid hydration problems. Although there were possible advantages to using a faster setting cement such as Type III, Type I was selected, given that it is the most readily available in the Nigerian market. Besides, it is the most commonly used type of cement for CBP fabrication (Wolfe and Gjinolli 1999). To improve the compatibility of cane furnish with cement, $CaCl_2$ was used as an additive. $CaCl_2$ was selected because it has been shown to be an effective and economical accelerator for cement hydration and has been widely adopted by the cement-wood board fabricators (Lee 1984; Wolfe and Gjinolli 1999). The parameters used for fabricating experimental panels are summarized in Table 2. Three-layered, 350-mm × 350-mm × 6 mm, 1,200 kg/m^3 density test specimens of particleboards consisting of coarse core and fine surfaces were produced, using a cement-cane mixing ratio (based on oven-dry weight of cane particles), of 2.5 to 1.0 at three additive concentration levels, i.e., calcium chloride of 2.5, 3.0, and 3.5 percent (based on weight of cement). The amount of water used in mixing furnish with the cement was based on experiments reported by Weatherwax and Tarkow (1964, 1967). They recommended the use of 2.7 ml of water per gram of furnish (adjusted to oven-dry basis) and 0.25 ml of water per gram of cement.

TABLE 2. *Parameters used in experimental board fabrications.*

Cane Pretreatment Temperature: 80°C
Cane Average Moisture Content: 12%
Cement Type: Type I
Chemical Additive: Calcium chloride
Cement-Cane Mixing Ratios (based on weight of cement and oven-dry weight of cane particles): 2.5:1.0; 2.75:1.0; 3.0:1.0; 3.25:1.0
Additive Concentration Levels: 2.5%; 3.0%; 3.5%
Board Type: 3-layered, consisting of coarse core and fine surfaces
Board Dimensions: 350 mm × 350 mm × 6 mm
Target Board Density Levels: 1,050 kg/m^3; 1,200 kg/m^3
Pressing Cycle: 1.23 N/mm^2

The quantities of cane, cement, water, and chemical additive required to make each board were measured and placed in separate polythene bags. Powdered $CaCl_2$ was dissolved in water and added to the cane particles. The quantity of cement required for the board was added to the wet cane particles and mixing was done manually until a homogeneous cement-cane mixture was obtained. The mixing procedures were carried out separately for the face and the core layers. The individual mixtures were then hand-formed into a mat inside a wooden deckle box placed on a metal caul plate. Three replications for each sample board were made. All the mats were tamped into the required board thickness of 6 mm with a pressure of 1.23 N/mm^2 on a manually operated hydraulic press. The boards remained under pressure for a period of 24 h. After the pressing cycle was completed, the boards were stripped of the caul plates and conditioned at a temperature of 21 ± 2°C and a relative humidity of 60 ± 2% for 15 days. The density (dry mass per unit volume as cured) of the samples from each board was determined by direct measurement.

Board test evaluation

At the end of the conditioning period, the boards were tested for static bending strength (MOR), stiffness (MOE), and water resistance in accordance with the ASTM D 1037-96a (ASTM 1998). For static bending tests, 200- × 50- × 6-mm specimens were used. They were loaded at the center of the span on a universal testing machine with the load applied to the finished face at a uniform rate. Load deflection curves to maximum load were obtained for all bending tests. The deflection at the center of each specimen was obtained by means of a dial gauge. The MOR and apparent MOE for each specimen were calculated using Eqs. (1) and (2), respectively:

$$\mathrm{MOR} = 3PL/2bd^2 \quad (1)$$

$$\mathrm{MOE} = P_l L^3/4bd^3 y_l \quad (2)$$

where

b = width of specimen (mm)
d = thickness (depth) of specimen (mm)
L = length of span (mm)
P = maximum load sustained by the board (N)
P_l = load at proportional limit (N)
y_l = center of deflection at proportional limit load (mm)

For WA and TS tests, 152- × 152- × 6-mm specimens, with all four edges smoothly and squarely trimmed, were used. Prior to testing, the weight and dimensions (width, length, and thickness) of each specimen were measured and recorded. The specimens were then submerged horizontally under 25 mm of distilled water maintained at a temperature of 20 ± 1°C for 48 h. The amount of water absorbed was calculated as the percentage by weight, based on the weight of each specimen. Thickness swelling was expressed as a percentage of the original thickness.

RESULTS AND DISCUSSION

Static bending strength and stiffness

The average MOR and MOE are shown in Table 3. The MOR values ranged between 0.5 N/mm^2 and 1.6 N/mm^2, while the MOE values ranged between 480 N/mm^2 and 3,563 N/mm^2. As shown in Table 4, the levels at which the density, additive concentration, and cement-wood mixing ratio were used in the experiments had no significant effects on MOR and MOE. However, the interaction among density, mixing ratio, and additive concentration was found significant for the MOE at the 0.05 level of probability. In conformity with the findings of Badejo (1989) and Wolfe and Gjinolli (1999), boards produced at the higher density (1,200 kg/m^3) had relatively higher MOR and MOE values than those produced at 1,050 kg/m^3. For example, there was a 100% increase in MOR and a 12% increase in MOE for boards produced at the same cement-cane mixing ratio of 2.75:1.0, $CaCl_2$ concentration of 2.5%, and densities of 1,050 kg/m^3 and 1,200 kg/m^3, respectively. Generally, boards produced with cement-cane ratio of 3.0:1.0 had relatively superior MOR and MOE values. A general increase in board MOR and MOE values with increase in $CaCl_2$ concentration level was also observed. Boards produced at 3.5% $CaCl_2$ had higher MOR and MOE values than those produced at 2.5% concentration.

The ranges of observed MOR and MOE values fall within the range of values reported by Badejo (1992) for CBP produced from ba-

TABLE 3. *Average values obtained for the strength and sorption properties of experimental CBP boards.*

Density kg/m^3	C.C.L.[1] (%)	M.R.[2]	MOR[3] (N/mm^2)	MOE[4] (N/mm^2)	TS[5] (%)	WA[6] (%)
1,050	2.5	2.5:1.0	1.0	3,563	2.8	44.7
		2.75:1.0	0.6	1,120	1.9	40.9
		3.0:1.0	0.7	2,170	1.5	38.6
		3.25:1.0	1.4	1,518	2.1	39.3
1,200	2.5	2.5:1.0	1.0	882	2.6	49.4
		2.75:1.0	1.2	1,252	3.9	51.3
		3.0:1.0	0.8	1,002	1.4	41.4
		3.25:1.0	1.2	849	1.4	38.8
1,050	3.0	2.5:1.0	1.2	705	2.7	46.3
		2.75:1.0	0.5	2,221	2.2	49.0
		3.0:1.0	0.7	2,352	1.5	41.9
		3.25:1.0	0.6	2,431	2.7	36.0
1,200	3.0	2.5:1.0	1.4	1,622	1.8	41.0
		2.75:1.0	0.9	1,483	1.9	45.8
		3.0:1.0	0.8	2,316	2.8	46.0
		3.25:1.0	1.0	1,676	1.1	40.8
1,050	3.5	2.5:1.0	1.1	1,464	2.3	38.9
		2.75:1.0	1.2	1,651	5.0	38.5
		3.0:1.0	1.4	1,041	8.6	33.5
		3.25:1.0	1.3	1,280	1.7	31.8
1,200	3.5	2.5:1.0	1.6	953	1.4	48.5
		2.75:1.0	1.5	1,105	1.7	32.3
		3.0:1.0	1.4	745	4.8	30.8
		3.25:1.0	0.8	480	1.9	37.0

[1] C.C.L. = $CaCl_2$ Concentration Level.
[2] M.R. = Mixing Ratio.
[3] MOR = Modulus of Rupture.
[4] MOE = Modulus of Elasticity.
[5] TS = Thickness Swelling.
[6] WA = Water Absorption.

gasse (MOR = 0.73 to 3.82 N/mm^2 and MOE = 2,090 to 3,270 N/mm^2), and other agricultural residues such as maize stalk (MOR = 1.18 to 5.08 N/mm^2 and MOE = 1,570 to 4,890 N/mm^2), and cotton stalk (MOR = 4.99 to 7.45 N/mm^2 and MOE = 1,770 to 3,000 N/mm^2). The MOR values are, however, lower than the mean values reported by Dinwoodie (1978) for CBP produced from selected softwood species (MOR = 11.3 N/mm^2 and MOE = 4900 N/mm^2) and the range of values reported by Badjo (1987) for selected tropical hardwood species (MOR = 6.21 N/mm^2 to 14.75 N/mm^2 and MOE = 2,100 N/mm^2 to

TABLE 4. *Analysis of variance for testing the effects of production variables on board properties.*

Source of Variation	Degree of freedom	Square mean values MOR	MOE	TS	WA
Density (D)	1	0.093	530695.43	0.685	5.88
Mixing ratio (MR)	3	0.004	14585.37	0.741	18.71
$CaCl_2$ concentration level (C.C.L.)	2	0.136	292515.21	1.097	31.01
D × MR	3	0.034	12891.07	0.007	0.70
D × C.C.L.	2	0.031	112390.60	0.645	2.35
MR × C.C.L.	6	0.018	129991.59	1.121	4.70
D × MR × C.C.L.	6	0.015	8296273.23*	0.409	7.29
Error	72	1.562	3126632.72	14.911	2193.75

* Significant at 0.05 level of probability.

3,500 N/mm^2). Also, the MOR values fall below, while the MOE values compare favorably with published range of values for commercial resin-bonded particleboard, (i.e., MOR = 5.5 to 14.0 N/mm^2 and MOE = 800 to 2,000 N/mm^2) (Badejo 1989).

Two major factors influencing the bending properties of CBPs, apart from density, cement-furnish mixing ratio, and additive concentration level, are the geometry of the furnish material, i.e., particle length and the aspect ratio, and the interfacial bonding between material constituents (Shi et al. 1999; Huang and Cooper 2000). Generally, bending properties increase as the particle size decreases due to increase in adhesion between cement and furnish. However, smaller particles may also have negative effects on the bending strength of the composite. Hence, there is always the need for particle geometry optimization. The relatively low MOR and MOE values observed in this study may be attributed to the relatively low aspect ratio of the particles used (i.e., 6:1 for face material and 8:1 for core material), the use of coarse particles in the core of the board, and possibly the inclusion of pith in the cane residues utilized. Long thin flakes generally tend to improve MOR and MOE (Badejo 1988; Onyemachi 1997; Huang and Cooper 2000), while inclusion of piths, which are thin non-lignified cells, may cause hydrolysis, thereby reducing the bending strength properties of CBPs (Kollman and Kuenzi 1975).

Interfacial bonding between constituent materials is a function of the compatibility between the furnish and Portland cement, i.e., the extent of bonding between furnish, and the cement is a product of how much the inhibitory effects of furnish on setting of cement are minimized. The general, though minimal, increases observed in the values of the two strength properties tested with higher levels of $CaCl_2$ concentration are an indication of the effectiveness of $CaCl_2$ in minimizing the detrimental effects of cement-cane interaction. Further investigations are, however, required to establish the reason for the relatively lower MOE values observed in boards produced at the density level 1,200 kg/m^3 and 3.5% $CaCl_2$ concentration level.

Water resistance

The mean values obtained for TS and WA are presented in Table 4. The ranges of values observed were 1.1 to 8.6%, and 30.8 to 51.3% for TS and WA, respectively. As shown in the analysis of variance in Table 4, the interaction among the three variables used for board production, i.e., density, cement-cane mixing ratio, and $CaCl_2$ concentration level, was not significant at 0.05 level of probability. Boards produced at lower density of 1,050 kg/m^3 had generally lower TS and WA properties than those produced at 1,200 kg/m^3. Generally, increases in the $CaCl_2$ concentration levels resulted in minimal random variations in both the TS and in WA values of the boards. Also, there were random variations on TS and WA properties of boards produced using different cement-cane mixing ratios.

The increases observed in TS and WA values with increase in board density may be attributed to the increase in cane content of the boards, given that more cane was added to maintain the same cement-cane ratio at the higher density level, thus making the boards more hygroscopic. Another plausible explanation for this observation is that the denser boards underwent greater compression during production and thus experienced more springback during immersion in water (Huang and Cooper 2000).

A possible contributory factor to the relatively low dimensional stability of the boards is the use of coarse particles in the core layer. Coarse particles contribute to poor bonding between cement and furnish unless there is an excess of cement (Huang and Cooper 2000). Hence, the use of coarse particles for the core may have reduced the bonding in this region. There is, however, a need for further studies on the effect of cement-cane mixing ratio and $CaCl_2$ concentration level on water resistance properties of the board. Badejo (1989) reported that an increase in $CaCl_2$ concentration tended to reduce the ability of CBPs to swell, while an increase in cement-wood mixing ratio tended to result in a decreased in WA properties.

The TS values compare favorably with the range of values reported by Badejo (1986) for CBP produced from selected Nigerian hardwoods when soaked in water for 72 h (TS = 2.2% to 5.7%), while the WA values are greater than the range of values reported by the same author for CBP from selected agricultural wastes when soaked in water for 24 h (WA = 0.10% to 38.10%). The WA values are lower than the average value reported by Biblis and Lee (1984) for southern pine plywood (WA = 60%), but are higher than the average value reported by Lee (1984) for cement excelsior boards made using pretreated particles generated from debarked southern pine logs (WA = 22%). The relatively high WA properties observed are an indication that the boards may be highly susceptible to fungi attack and may, therefore, not be suitable for exterior (wet) use. Previous studies by Badejo (1998) showed that WA properties may be improved upon by laminating CBPs with veneers.

CONCLUSIONS

The following conclusions were drawn from the findings of this study:

(1) It is technically feasible, on a laboratory scale, to fabricate cement-bonded particleboard from chopped strands of pretreated mixed rattan furniture waste. The investigation supports the assumption that rattan furniture waste is a potential valuable raw material for the CBP industry.

(2) The strength and water resistance properties of the boards indicate possible use as low-stressed materials for indoor (dry) applications. Such uses may include structural applications requiring sound absorption and energy dissipation where low bending strength and water resistance properties are not necessarily limiting.

RECOMMENDATIONS FOR FURTHER STUDIES

Further investigations are required to reveal the full potential of cement-bonded cane particleboard. The effects of more fabrication variables should be studied to provide guidelines necessary to adequately control the fabrication process and optimize material properties. These studies should be focused primarily on the possibility of enhancing the mechanical and water resistance properties of the board and should entail considering a wider range of densities, evaluating the effects of panel thickness, cane de-pithing, thinner flakes, veneer lamination, and blending of cane with other stronger, water-resistant materials, on board strength and sorption properties.

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