Flooring Panels from Cement-bonded Particleboard Substrate Overlaid with Brazilian Wood of Tauari

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Abstract

Cement-bonded Particleboards (CBPB) were produced with wood particles of *Eucalyptus urophylla*, Portland cement as binder and $CaCl_2$ as additive, in a nominal density of 1.4 g/cm^3. After the normal curing time of 28 days, the CBPB were overlaid in only one face with 6.0 mm-thick lumber of tauari (*Couratari stellata*), assembled with four types of glues: two polyvinyl acetate (PVA), one resorcinol and one PVAc cross linking, for use on dry flooring systems. The flooring panels presented good mechanical resistance, with modulus of rupture (MOR) ranging from 15.2 to 19.6 MPa, and dimensional stability, with maximum thickness swelling of 4.5% after 24 hours. The Janka hardness (face and base) varied from 8,100 to 11,222 N. The application of the flooring assembled with the four tested adhesives can be accomplished, however, if the place to be serviced presents high relative humidity the flooring must be used only when coated with two of the tested glues (resorcinol and one cross-linking).

Keywords: Overlaid Cement-bonded Particleboard, *Eucalyptus urophylla*, flooring Panels

Introduction

Cement-bonded Particleboard (CBPB) is a composite similar to the resin bonded medium density particleboard (MDP). It is composed basically of particles of wood, cement and water, in a proportion of generally 1.0:3.0:1.5 (based on mass). Chemical additives have been employed with the purpose of reducing the hardening time of the cement, which accelerates the development of resistance. According to Hachmi and Campbell (1989), the CBPB composite is the only structural panel that is highly resistant to fire, rotting and insects, yet, Dinwoodie (1978), affirms that it is very stable. Furthermore, the composite incorporates excellent insulating and thermo-acoustical characteristics and still ease of workability.

In the last 20 years, as stated by Watai (1996), the housing building industry has been experiencing changes as a result of the increasing use of the reconstituted wood panels, such as oriented strandboards (OSB) and waferboards. Not less important are the CBPB, possessing a long history of application and acceptance in the civil construction sector, mainly in the Europe and Asia, with an output of 2.4 millions of m^3 in 1993.

The area of planted forests in Brazil in 2006 was 5.7 millions of ha and has shown to be very productive. The participation of *Eucalyptus* sp. alone is 3.5 million of ha. According to Ponce (1995), this advantage has been benefiting the industries of pulp and paper, steel-makers, and wood-resin bonded panels. The utilization of this species in the wood-cement bonded panels' manufacture is still inexpressive.

A number of researchers (Weatherwax and Warkow, 1964; Davis, 1966; Biblis and Lo, 1968; Singh, 1975; Moslemi et al., 1983; Shukla et al., 1984; Teixeira and Guimarães, 1989; Souza, 1994; Latorraca et al., 1999) have been directing researches aiming to meet solutions to the problems that most interfere in the manufacture of CBPB. Along with this line of study, two issues stand apart, the physical and chemical interactions between the wood and the binder and the reduction of the curing time of the panels.

Among the various applications, this composite material can be used for dry flooring systems on timber frame constructions. In contrast to fibrous cement panels, the stabilizing elements of CBPB are the wood fibers from coniferous woods, mainly of the genera *Pinus*.

Flooring is, until today, one of the most valuable wood-made products. Not only solid flooring but engineered flooring made with Brazilian tropical species have good acceptance in the international market, mostly Europe and the United States of America. Its good design, quality, natural durability and exotic colors and grain figures explain this preference by the international markets.

Wood flooring can swell or shrink according to the conditions of the environment where it is applied. The combination of wood and wood-based panels can overcome or diminish this problem. In this matter, CBPB has a special characteristic of good dimensional stability.

The main objective of this work was to evaluate the potential of *Eucalyptus urophylla* as raw material for CBPB production, followed by veneer overlay aiming the utilization of the panels for floorings.

Materials and Methods

Raw Material

The panels of CBPB were produced with particles of *E. urophylla* from a plantation site of the Rural Federal University of the State of Rio de Janeiro (UFRRJ), southeast of Brazil. The cement Portland HIR (High initial resistance), a special kind of cement produced by some cement industries of Brazil, was used as binder. Calcium chloride ($CaCl_2$) was added with the function of eliminating the harmful effects of chemical substances of the wood and also to accelerate the setting of the cement.

Timber Collection

Five trees of *E. urophylla* were collected at random. Each tree was cut in 2 meter-long logs, properly identified and transported to the Wood Panels Laboratory of the UFRRJ. From each log it was obtained a disk section for testing the wood to cement compatibility.

Preparation of the Particles

The logs were processed in a rotary cut disk flaker and afterwards in an agricultural grinder to be classified in a set of screeners. The particles that passed for the sieve of 0.61 mm of opening were used for the surface layers of the CBPB and those that passed for the sieve of 2.08 mm and stayed retained in the sieve of 0.61 mm were classified for the core layer.

Panels Manufacture

The methodology utilized to calculate the materials for manufacture of the panels is that suggested by Souza (1994). The following fixed parameters were used:
Wood: cement Ratio = 1:3;
Water: cement Ratio = 1:2.86 (35% water on the mass of cement);
Density of the panels = 1.4 g/cm^3;
Dimensions of the panels = 40x 40x1.5 cm;
Quantity of replications per treatment = 3 panels;
Pressing = pressure of 4.0 MPa for 24 h at room temperature.

The panels were composed of three layers, 40% in the faces and 60% in the core. The cement, the particles of wood, water and the additive ($CaCl_2$) were mixed earliest. Cement was immediately added to the wet particles. Boards with dimensions of 400 mm of width and 400 mm of length were pressed at 4.0 MPa with the use of metallic clamps. After 24 hours pressing time the package, still clamped, was transferred to a room with controlled conditions of temperature and relative humidity of (20±3)^{o}C and (65±5)%, respectively, for remaining 28 days.

Assembling the flooring Panels

The CBPB panels manufactured were finished by overlaying one face with wood boards of tauari (*Couratari stellata*) for the floorings assemblage as seen in Figure 1. The wood boards of tauari were obtained in a circular saw in the dimensions of 70x15 cm, smoothed and sanded to final thickness of 6.0 mm. Each floor panel of CBPB was trimmed to 37x37 cm.

Fig. 1. *CBPB flooring assembly with wood of tauari as finishing*

Four kinds of glues were used in assembling the wood to the CBPB panels (Table 1):

Table 1: *Types of glue utilized in the assemblage of the floors*.

Codes	Types of glue	Composition
A503	Rhodopas A503	PVA
A602	Rhodopas A602	PVA
RS	Cascophen RS - Resorcinol	Phenolic
WB	Adhesive WB 9325 LFF	PVAc cross linking

The glues A503, A602 and RS are commercial adhesives, being the two first PVA bases (white glue) and the last one a phenolic adhesive with cure at room temperature and waterproof. The WB glue is also a commercial cross linking, based on PVAc that offers good protection against water, used with five parts of a catalyst Cl. The bond was sufficient to maintain the parts in contact and do no damage to the flooring panel. The pressing time was 24 hours at room temperature. After drying, the flooring panels were maintained in a room with controlled temperature and relative humidity.

Physical-Mechanical Tests

Mechanical Tests
The panels were tested in static bending - modulus of elasticity (MOE), modulus of rupture (MOR) and stress in the proportional limit (SPL), Janka hardness on the upper face, obtained in the face of the floor with finishing, and lower face, obtained in the face without covering, accoding to ASTM D1037 (1999) standard.

Physical Tests
In the tests of thickness swelling (TS) and water absorption (ASTM D1037) the specimens were not entirely immersed in water, but put in a tray of aluminum with water up to half of their height (Fig. 2). This procedure was adopted in order to simulate the infiltration of coming water from the under-floor, since the flooring panels are predicted for internal use.

Fig. 2. *Samples of CBPB flooring in the test of thickness swelling and water absorption.*

Statistical Analysis
The results obtained of the physical and mechanical tests were evaluated by analysis of variance for the different types of glues. The average values of the treatments were compared by the TUKEY test at the level of significance of 5% when the null hypothesis was rejected by the analysis of variance.

Results

The results of the physical tests are presented in Table 2. The density at 12% moisture content of the floor mounted with wood of tauari (density of 0.792 g/cm^3) varied from 1.16 to 1.19 g/cm^3 and there was no significant statistical difference regardless the glue used. That results from the fact that in the composition of the flooring panels with tauari, a smaller proportion regarding the total volume is CBPB, whose density is well bigger than that of tauari laminate.

Overall, flooring panels finished with the RS, WB and A602 glues presented higher dimensional stability when exposed to high humidity. The glue A503 conferred the least stability to the flooring panels assembled. Only samples with the glues that are not PVA basis (RS and WB) were intact after the test in water, without detachment of the cover layer. The glues A503 and A602 did not resist to the test of humidity and, despite the good dimensional stability, the finishing detached from the CBPB. In fact, the dimensional stability is conferred by the wood-cement panel. It is a good finding since the stability of the flooring is important in avoiding shrinkage after mounted.

Table 2. *Results of the physical properties of the flooring panels.*

Treatment	Density (g/cm^3)	TS 2h* (%)	TS 24h (%)	WA 2h (%)	WA 24h (%)
A503	1.16 **a** (0.03)	3.2 **b** (0.87)	4.5 **b** (1.62)	12.16 **a** (2.31)	15.67 **a** (2.49)
A602	1.19 **a** (0.04)	2.2 **a** (0.85)	3.3 **ab** (0.95)	10.16 **a** (3.55)	14.26 **a** (4.01)
RS	1.18 **a** (0.04)	1.8 **a** (0.31)	2.5 **a** (0.28)	9.52 **a** (2.43)	12.36 **a** (2.49)
WB	1.18 **a** (0.03)	1.9 **a** (0.36)	3.0 **a** (0.61)	10.25 **a** (2.16)	13.87 **a** (2.08)

Note*: Numbers in parenthesis are standard deviation. Means with same letters in a column are not different at 5% significance level according to the Tukey test. (*) TS 2h/TS 24h = Thickness swelling after 2 and 24 hours; WA 2h/WA 24h = Water absorption after 2 and 24 hours.*

The results of the mechanical properties are presented in the Table 3.

Table 3. *Results of the mechanical properties of the flooring panels.*

Treatment	MOR (MPa)	MOE (MPa)	SPL (MPa)	Hardness face (N)	Hardness base (N)
A503	16.4 **a** (1.9)	7,072 **a** (1,246)	9.6 **a** (1.1)	8,100 **a** (1,181)	8,960 **a** (896)
A602	19.6 **b** (1.9)	7,937 **a** (916)	12.0 **b** (1.7)	8,678 **ab** (1,011)	10,058 **ab** (858)
RS	17.5 **ab** (1.6)	7,704 **a** (1,051)	11.0 **ab** (1.4)	8,372 **ab** (1,364)	9,327 **a** (1,773)
WB	15.2 **a** (0.9)	7,518 **a** (518)	10.4 **ab** (0.7)	9,854 **b** (1,062)	11,222 **b** (1,229)

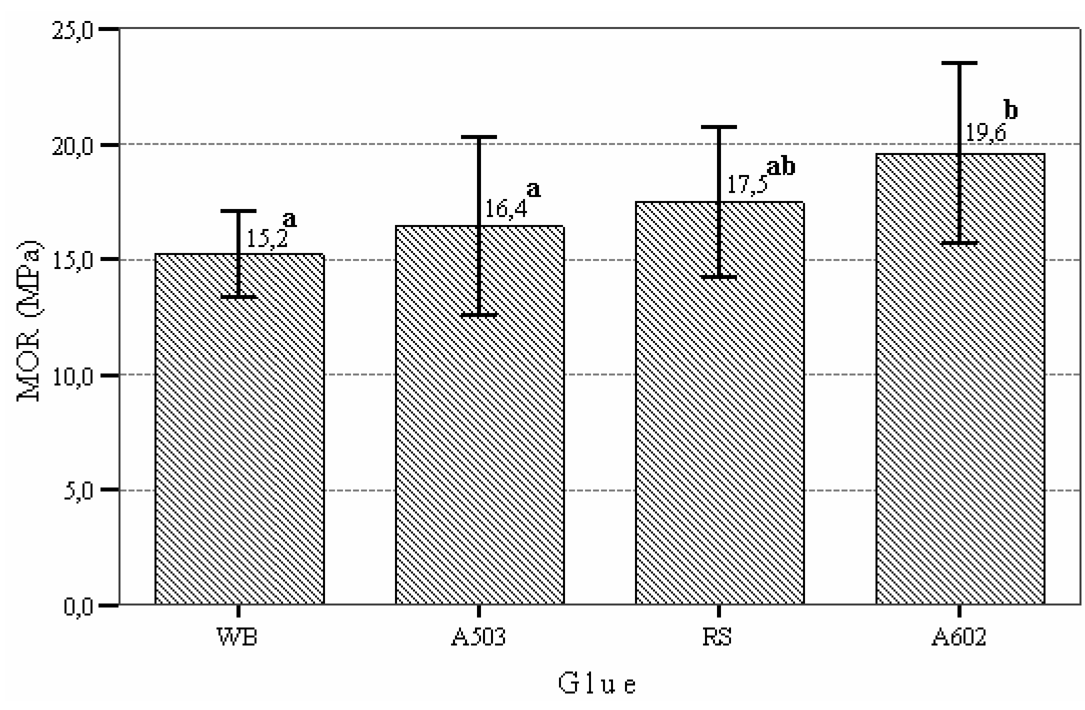
Note*: Numbers in parenthesis are standard deviation. Means with same letters in a column are not different at 5% significance level according to the Tukey test.*

Regarding Janka hardness, the flooring panels overlaid with the glue WB presented the higher values of resistance. The values of hardness of face or base varied from 8,100 to 11,222 N. These values are well above the requirements of the CSA O437.0 standard for OSB panels (2.224 N) and almost two fold the Janka hardness of wood of *Cupressus glauca* Lam. (4,809 N) in the dry-condition as reported by Okino et. al (2006).

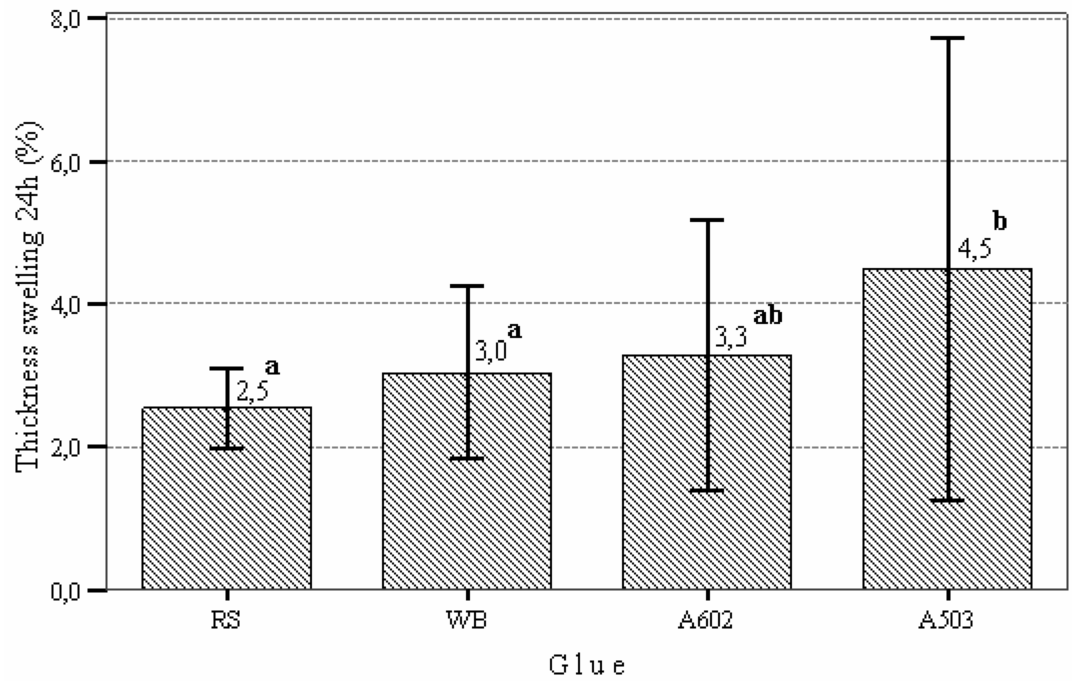
The MOE did not present significant difference as far as the type of glue used in the overlay and ranged from 7,072 to 7,937 MPa. The same behavior was not observed regarding the MOR, where samples of CBPB overlaid with the glue WB presented lower resistance than those with the glues A602 and RS. However, the total difference was not prominent, the MOR varied from 15.2 to 19.6 MPa.

The values of MOR and MOE are well above the requirements of Bison (1978) for type HZ structural panels. This type HZ panels are used for wall cladding and supports loads of 9 MPa in MOR and 3,000 MPa in MOE. Besides, it is resistant to rotters and exterior environmental conditions. Bison is one of the pioneers in the manufacture of CBPB.

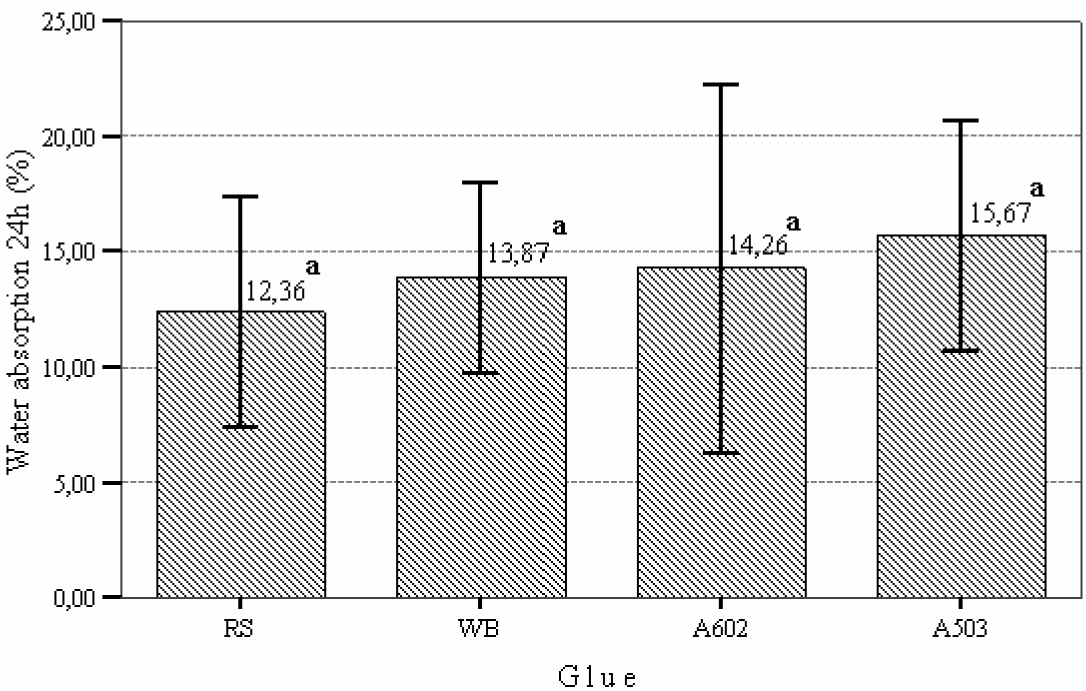
The Graphs 1 to 3 show the values of MOR, thickness swelling and water absorption after 24 hours, taking in account the type of glue applied in the overlaying.



Graph 1. *MOR of the CBPB flooring panels*.



Graph 2. *Thickness swelling of the CBPB flooring panels, after 24 hours of immersion.*



Graph 3. *Water absorption of the CBPB flooring panels s, after 24 hours of immersion.*

Conclusions

The assembled flooring panels presented good mechanical resistance and can be used if applied straightly to a substrate. If applied like suspended floor, it must be observed the span to be used in service.

The hardness of the floors also was sufficiently high for its application.

An important issue is the dimensional stability, which is the variation of the dimensions when exposed to high humidity. In this matter, the response of the flooring panels mounted with the resins of resorcinol (RS) and cross-link (WB) was positive in the gluing line between the substrate (CBPB panel) and the overlay used (wood laminate).

It is not recommended the use of the flooring panels with PVA basis finishing in places of high humidity or exposed straightly to water.

This kind of flooring panels may be a good option for the utilization of wood residues, mainly from reforestation.

References

American Society for Testing and Material. ASTM D 1037-78B: 1999. Standard methods of evaluating the properties of wood-base fiber and particle panel materials. In: Annual Book of ASTM Standard, Philadelphia.

Biblis, E.J. & Lo, C.F. 1968. Sugars and other wood extractives: effect on the setting of Southern pine-cement mixtures. Forest Prod. J. 18(8):28-34.

Bison wood-cement board. 1978. Bison - Report. p.10.

Davis, T.C. 1966. Effect of blue stain on setting of excelsior-cement mixtures. Forest Prod. J. 16(6):49-50.

Dinwoodie, J.M. 1978. Wood-cement particleboard. Building Research Establishment. Abstract.

Hachmi, M. and Campbell, A.G. 1989. Wood-cement chemical relationships. In: Inorganic Bonded Wood and Fiber Composite Materials, Session II: Raw Material Considerations. USA, Vol. I, p. 43-47.

Latorraca, J.V.F; Iwakiri, S.; Lelis, R.C.C. 1999. Efeito inibidor de cinco espécies florestais sobre a cura do compósito cimento-madeira. Floresta e Ambiente 6(1):76-82.

Moslemi, A.A.; Garcia, J.F. ; Hofstrand, A.D. 1983. Effect of various treatments and additives on wood-Portland cement-water systems. Wood and Fiber Sci. 15(2):164 -176.

Okino, Esmeralda Y. A.; Camargos, José A. A.; Santana, Marcos A. E.; Marques, Márcia H. B.; Martins, Varlone A.; Sousa, Maria E. de; Teixeira, Divino E. 2006. *Cupressus glauca* Lam. wood characteristics. Scientia Forestalis 72(2006):39-48.

_____. 1989. Wood-cement panel products: coming of age. In: Inorganic Bonded Wood and Fiber Composite Materials, Session I: State of the art in mineral-bonded boards. USA, VOL, I, p.12-18.

Ponce, R.H. 1995. Madeira Serrada de Eucalipto: Desafios e Perspectivas. In: Seminário Internacional de Utilização da Madeira de Eucalipto para Serraria. São Paulo, p.50-58.

Shukla, V.K.; Jain, V.K.; Pant, R.C. 1984. Suitability of Lignocellulosic Materials for the Manufacturing of Cement Bonded Wood-Wool Boards. Timb. Dev. Assoc. 30(3): 16-23.

Singh, N.B. 1975. Influence of calcium gluconate with calcium chloride or glucose on the hydration of cements. Cement and Concrete Res. 5(6):545-550, United States.

Souza, M.R. 1994. Durability of cement-bonded particleboard made conventionally and carbon dioxide injection. Idaho, Thesis (Doctor of Philosophy), University of Idaho, 123 p.

Teixeira, Divino.E. & Guimarães, Tânia L. 1989. Tratamento de partículas de *Acacia mearnsii* De Wild. para produção de chapas de cimento-madeira. Brasília: IBAMA - DIRPED - LPF, Série Técnica 11.

Watai, L.T. 1996. Painéis estruturais. Tendências e desenvolvimento no Brasil. Revista da Madeira 5(2): 32-34.

Weatherwax, R.C. & Warkow, H. 1964. Effect of wood on setting of Portland cement. Forest Prod. J. 14(12):567-570.