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# Effect of Battens Edge Bonding in the Properties of Blockboards Produced with *Pinus* sp. Recycled from Construction Sites

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author DET designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MPFM managed the analyses of the study, data collection and the literature searches. Both authors read and approved the final manuscript.*

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## ABSTRACT

The construction is an activity that generates large amounts of waste, demanding alternative reuse. Wood-based waste can be processed and used for the production of forest products, such as blockboards type plywood. This study evaluated the physical and mechanical properties of blockboards produced with wood from construction wastes, comparing the core bonded and without bonding the strips, in order to determine which production method shows better results as well as observe the phenol-formaldehyde adhesive properties in the panels. The production of blackboard as well as testing was made at the Forest Products Laboratory-LPF, Brazilian Forest Service - SFB. The wood wastes used were obtained in construction sites at the University of Brasilia-UnB, and the species used was *Pinus* sp. for the battens and Currupixá (*Micropholis venulosa*) for the face veneers. The adhesive used was phenol-formaldehyde (Cascophen HL-7090 HS). The panels were produced with dimensions 560 x 340 mm x 15 mm. The physical properties of the panels were assessed: moisture content (MC); apparent density (MEA); water absorption (AA); and recovery in thickness (RE) and swelling plus recovery in thickness (IR). The

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mechanical properties of the panels were evaluated: static bending (MOR and MOE); and shear strength in the glue line (RLC). In view of the source of the material used, the results were satisfactory for both treatments.

*Keywords: Construction; wood waste; blockboard.*

## 1. INTRODUCTION

In construction sites, virtually all activities generates wastes, also called debris or construction and demolition wastes (CDW), or, as has currently been named, civil construction waste (CCW). According to [1], the CDW may correspond to more than 50% of the mass of municipal solid wastes. The generation of wastes in construction can occur at different stages of the life cycle structure - construction, maintenance and renovation and demolition and the main wastes generated in these stages are sand, gravel, mortar, concrete, plastic, metal, glass, paper and pieces of wood. Such a building model had no problems until recently, due to the abundance of natural resources [1].

According to [1], the intensification of the industrial activity, as well as the development of new technologies, population growth, increase in people in urban areas and diversification of consumer goods and services, the waste is a serious urban problem, in addition to being complex and costly to management, considering its volume and the very large amount. Also the resources become scarcer, so reducing their demand or using wastes materials has become of great importance.

From these problems it was found that there was great need to implement adequate solid waste management systems. For the preservation of natural resources, wastes can be recycled, extending the life of natural reserves and reducing the destruction of the landscape, flora and fauna [1].

Regarding wood in the Brazilian civil construction, it is used in the construction in a temporary way, for example, forms for concrete, scaffolding, supporting and also definitively as roof structures, window frames, ceilings and floors. The scarcity of studies on recycling timber coming from civil construction wastes points to the importance of research like that developed by Silva [2].

As well as the construction industry, the timber industry is a major generator of wastes from the wood processing. The wood processing to adapt to market demands generates wastes such as sawdust, battens, shavings, shorts, etc. [3]. Currently, much of this waste and the construction remaining are used for energy, with little reuse for the production of higher value added products. Furthermore, according to [3], the supply of residues exceeds the demand, and the material often has no specific purpose.

The material from products like wood or solid wood, when collected, constitutes a source of fibers that after appropriately processed can be the basis for production of forest products, such as bonded panels and laminates, furniture components, finishing panels and plywood [4]. Teixeira and Silva [5] reported the use of wood waste from various species in the production and properties of blockboard.

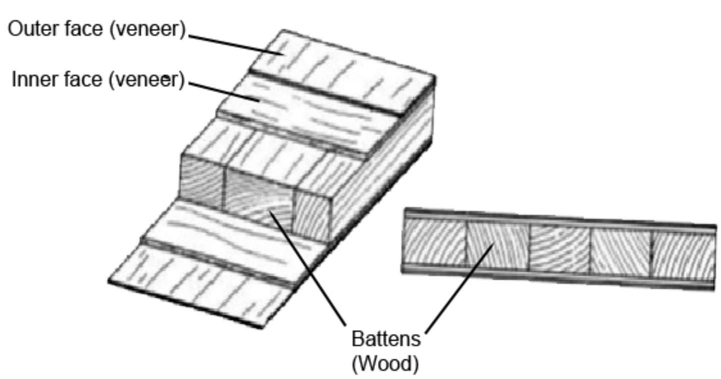


**Fig. 1. Construction principle of blockboard**
*Source: Mendes et al. [7]*

The blockboard can be used for the manufacture of furniture, partition panels, among others carpentry services [6]. However, the production in Brazil is still reduced, reaching only 25% to 35% of the plywood production and consumption is 0.25-0.35 m³ per cubic meter of laminated plywood [7]. Fig. 1 shows a representation of the blockboard.

According to [2], the production of blockboard type plywood from wood wastes is a good option for smaller parts, usually discarded, but when reused as part of the material gain value and have functionality for other purposes. The literature on the utilization of wood wastes from CCW for plywood production is limited.

The objective of this study is to determine the physical and mechanical properties of a blockboards made from construction waste using a phenol-formaldehyde adhesive, with and without bonding the core battens.

## 2. METHODOLOGY

This work was carried out at the Forest Products Laboratory-LPF of the Brazilian Forest Service-SFB.

### 2.1 Obtaining Wood Wastes

The residues were collected in construction sites carried out at the University of Brasilia-UNB Campus Darcy Ribeiro. The pieces collected were lumber of *Pinus* sp. after using as concrete forming.

### 2.2 Waste Processing

The residues were then processed according to established by the technical standards for adjustment and finishing of measures and subsequent bonding procedure. For processing the material it was used a circular saw, a thicknesser and a planner.

The processed material was then stored in an air conditioning room of the LPF under controlled conditions of temperature (20±3)°C and relative humidity (65±5)%, to constant mass and approximate humidity of 12%, considered ideal for bonding.

### 2.3 Production of Blockboards

Two types of blockboards were produced: one with edge gluing the core battens and the other without gluing. Both were made with strips of *Pinus* sp. and double face layers (front and back) of veneers of currupixá wood (*Micropholis venulosa*), on each side of the blockboard, with medium density of 0.805 g/cm³ and thickness of 0.65 mm.

For each treatment (with and without edge gluing) three panels were produced, adding a total of 114 battens on the manufacturing. Each individual batten measured 35x3x1.5 cm (length x width x thickness).

In the treatment NG (no edge gluing the battens), the core battens were edge joined by simply clamping, in preparing to receive the face veneers. The clamps were removed after pressing. First the back veneers were glued, with grain direction perpendicular to the battens grain and then the outer veneer with the fibers in the parallel direction. In the WG (with battens edge gluing) treatment, the core battens were edge glued with PVA (polyvinyl acetate) using a gramature of 100 g/m² prior to bonding the face veneers. Fig. 2 illustrates the pressing procedure with the clamps.

**Fig. 2. Pressing procedure of the core battens**

The process of gluing the core panels to the front and back face veneers was made by using the adhesive phenol formaldehyde Cascophen HL - 7090 HS in a gramature of 200 g/m². It is a liquid resin based in aqueous solution, developed especially for the bonding of wood of all kinds, where the primary demands are high quality and fully waterproof bonding. The hot pressing was made in a hydraulic press Indumec with 3.5 minutes pressing time, a constant temperature of 130℃ and pressure of 1.0 MPa.

## 2.4 Obtaining the Specimens for Testing

After making the panels and air conditioning, the specimens were cut from each board for testing. Three specimens were cut from each panel with direction parallel and three with direction perpendicular to the core battens. The scheme described can be seen in Fig. 3.

## 2.5 Evaluation of Physical Properties of Panels

### 2.5.1 Moisture Content (MC)

The standard for plywood used for determining the moisture content was ABNT NBR 9484 [8]. For each treatment 27 specimens were used, obtained from specimens after the bending test.

The initial mass was determined from the samples conditioned using a digital scale Bel with resolution of 0.01 g. To obtain the dry mass, the samples were placed in an oven at (103±2)℃ and monitored to reach constant mass. The moisture content was obtained using Equation 1.

$$MC = \frac{M_i - M_d}{M_d} \times 100 \quad (1)$$

Where:

MC = Moisture content, %;
$M_i$ = Initial mass conditioned, g;
$M_d$ = Bone dried mass, g.

### 2.5.2 Apparent density

To calculate the apparent density, the tests were conducted in accordance with the NBR 9485 [9] standard for plywood using the specimens of the bending test, nine from each direction of fibers. The specimens were conditioned at (20±3)℃ and (65±5)%, to reach equilibrium moisture content of 12%. Measures of mass, using a scale Bel with resolution of 0.01 g, length, width and depth, using a digital caliper Mitutoyo with resolution of 0.01 mm, of each sample was taken and apparent specific density calculated using Equation 2.

$$MEA = \frac{M_i}{L \times W \times D} \quad (2)$$

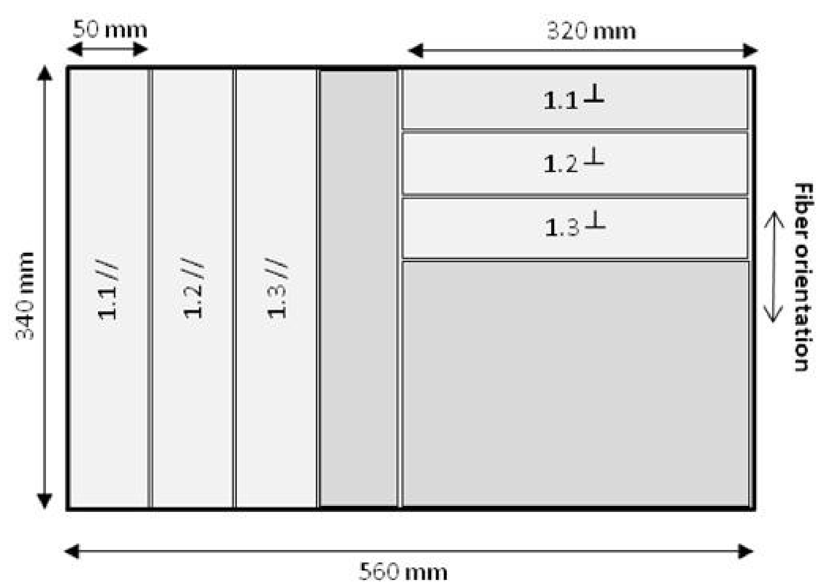


**Fig. 3. Sketch representing the cut panel for removal of specimens**

Where:

MEA = apparent specific density, g/cm³;
$M_i$ = Initial mass conditioned, g;
L, W, D = length, width and depth, respectively, mm.

#### 2.5.3 Water absorption

For this test, 36 specimens per treatment were used, according to the ABNT NBR 9486 [10] standard for plywood, following the procedures and calculated as Equation 3:

I. Oven drying at (50±2)℃ for 24 hours;
II. Cooling in desiccator;
III. Weighing, 0.01 g precision scale ($M_i$);
IV. Immersion in distilled water at constant temperature of (25±2)℃ for 24 hours;
V. Fast drying on paper towels; and
VI. Weighing again, 0.01 g precision scale ($M_f$).

$$WA = \frac{M_f - M_i}{M_i} \times 100 \quad (3)$$

#### 2.5.4 Recovery in thickness (RE) and swelling plus recovery in thickness (IR)

According to ABNT NBR 9535 [11] standard for plywood, swelling is the increase in thickness of the plywood when subjected to water absorption. Still according to the standard thickness recovery is the ability to regain the initial plywood thickness after immersion in water and subsequent drying.

For each treatment 72 specimens were used, being 36 for the control sample and 36 for the immersion test. Specimens were conditioned to reach constant mass. For the control specimens, a thickness measurement using a digital caliper Mitutoyo with resolution of 0,01 mm was made in the central part of the sample after conditioning and another after drying in an oven at (103±2)℃ for 24 hours.

The test specimens were measured after conditioning and then immersed in distilled water at (20±2)℃ for 24 hours. The measurement was made with saturated specimens and subsequent drying in an oven at the same temperature mentioned above for 24 hours, taken as the final measurement of the dry specimen. The recovery in thickness (RE) was calculated according to Equation 4.

$$RE = \left(\frac{e1\,.e5}{e2\,.e3} - 1\right).100 \quad (4)$$

Where:

RE = recovery in thickness, %;
e1 = sum of thicknesses of specimens used as a control, conditioned, mm;
e2 = sum of thicknesses of specimens used as a control, oven dried, mm;
e3 = sum of thicknesses of specimens before immersion in water, mm;
e5 = sum of thicknesses of specimens after immersion in water, mm.

The thickness swelling plus recovery in thickness (IR) was calculated according to Equation 5.

$$IR = \left(\frac{e1\,.e4}{e2\,.e3} - 1\right).100 \quad (5)$$

Where:

IR = thickness swelling more recovery in thickness, %;
e4 = sum of thicknesses of specimens after immersion in water, and after oven drying, mm.

### 2.6 Evaluation of Mechanical Properties of Blockboards

#### 2.6.1 Resistance to static bending

The standard EN 310 [12] was used to calculate the modulus of elasticity (MOE), modulus of rupture (MOR) and stress at Proportional Limit (SPL) of specimens using a Universal testing machine Instron with capacity of 300kN. The SPL was determined using the load and deformation at proportional limit at testing span of 290 mm and average testing speed of 9.0 mm/min.

#### 2.6.2 Resistance to shear in bonding test

As the Brazilian standard does not provide the shear test in the glue line to blockboards, the tests were based on the European standard EN 314-1 [13] and EN 314-2 [14] using a Universal testing machine Emic with capacity of 300kN. Fifteen specimens were used for each treatment, with 25 mm of width and distance between the grooves of 25 mm. For the shear boiling test, specimens were immersed for 24 hours in water at (20±3)℃, boiled for 6 hours and again immersed in water for one hour. They were then subjected to load at a constant speed of 6.0 mm/min, according to ABNT NBR 9434 [15].

Equation 6 was used to determine the resistance to shear strength.

$$Tr = \left(\frac{F_{max}}{a\,.b}\right) \quad (6)$$

Where:

Tr = maximum tension in shear, MPa;
$F_{max}$ = tensile strength, MPa;
a = distance between grooves, cm;
b = width of specimen, cm.

#### 2.6.3 Dynamic modulus of elasticity analysis - stress wave

Stress Wave Timer method is a non-destructive test used to measure the dynamic elastic modulus of a specimen. The method is based on the speed of propagation of stress waves in the material, which is directly related to the material density. For this calculation, Equation 7 was used.

$$MOE_d = V^2 \times MEA \times \frac{1}{g} \quad (7)$$

Where:

$MOE_d$ = dynamic modulus of elasticity, kgf/cm²;
V = speed of propagation of the tension wave, cm/s;
MEA = apparent specific density, g/cm³;
g = gravitational acceleration, 9.8 m/s².

### 2.7 Analysis of Results

Test data for analysis, were tabulated and the statistical analysis conducted using Microsoft Excel 2013. The software averages t test at 5% significance was used to analyze the results.

## 3. RESULTS AND DISCUSSION

### 3.1 Evaluation of Physical Properties of Panels

#### 3.1.1 Moisture content

The moisture content of the test specimens after air conditioning are presented in Table 1.

It is observed that the value of *P* is greater than 0.05, so the average of the difference of moisture content was not significant. The coefficient of variation shows that the WG treatment values had higher variability. The moisture values were close to expected.

Silva [2] found very similar values while doing the experiment with blockboards also produced from wastes and [16] obtained moisture content values close to 12% in plywood of *Pinus taeda*.

The National Program of Wood Quality (PNQM) determines the maximum moisture content of 18%, so the results were satisfactory.

#### 3.1.2 Determination of the apparent specific density (MEA)

The results for the apparent specific density of the test treatments are shown in Table 2.

It is observed that there is no significant difference of MEA between the treatments according to the t test.

**Table 1. Results of moisture content for the blockboards**

| Treatment | Factor | Mean | Standard deviation | Coefficient of variation (%) | *P* (T<=t)* bi-caudal |
|---|---|---|---|---|---|
| NG | MC (%) | 13.60 | 0.35 | 2.59 | 0.11 |
| WG | MC (%) | 13.05 | 2.28 | 17.47 | |

**P = .05, the difference is significant at the 5% significance level*

**Table 2. Results of the apparent specific density for the blockboards**

| Treatment | Factor | Mean | Standard deviation | Coefficient of variation (%) | *P* (T<=t)* bi-caudal |
|---|---|---|---|---|---|
| NG | MEA (g/cm³) | 0.54 | 0.026 | 4.770 | ns 0.780 |
| WG | MEA (g/cm³) | 0.53 | 0.029 | 5.531 | |

**P = .05, the difference is significant at the 5% significance level*

#### 3.1.3 Determination of Water Absorption (WA)

The values of WA obtained for the treatments, after immersion for 24 hours in water, are shown in Table 3.

Results show a significant difference between treatments according to the t test. The treatment NG, without edge gluing the battens, showed a greater susceptibility to water absorption. This can be explained by the smaller amount of glue on this material, conversely, in the WG treatment there is the edge gluing the battens with PVA adhesive, which provides less free spaces for water intake in the material.

#### 3.1.4 Recovery in thickness (RE) and thickness swelling more recovery in thickness (IR)

Tables 4 and 5 show the values obtained for RE and IR, as well as the statistical analyzes and the results observed.

From the table, one can observe that the average IR treatments presented significant difference at 5% significance level, with the WG treatment presenting higher mean and higher variability, as seen by the coefficient of variation. This can be explained by a possible inhomogeneous distribution of the adhesive during bonding in the material, which influences the swelling characteristics. Silva [2], using blockboards from construction waste obtained IR values close to 2%, i.e., comparable to values obtained in this work. Cabral [16], using multilaminate panels of *Pinus taeda* found IR values greater than 6%, however the adhesive used was Urea-formaldehyde.

For the average recovery in thickness (RE), the values do not differ significantly for the treatments at 5% significance level and again the variability (coefficient of variation) in relation to the WG treatment average was higher.

The thickness swelling of plywood panel is a result of water uptake as well as release of pressing tensions. Swelling can affect the pressing time, pressing temperature and type, proportion and formulation of the adhesive used [16].

### 3.2 Evaluation of Mechanical Properties of Blockboards

#### 3.2.1 Static bending

To define the feasibility of wood panels for structural use, it is important to determine the elasticity (MOE) and strength (MOR) of the material. Furthermore, it is also important to calculate the SPL, as this value indicates the stress at proportional limit, which is the tension when deformation changes from the elastic to the plastic regime, meaning that the material may suffer rupture at any time beyond this point. In Table 6 we can see these average values of MOR, MOE, and SPL obtained for the treatments studied.

**Table 3. Results of water absorption for the blockboards**

| Treatment | Factor | Mean | Standard deviation | Coefficient of variation (%) | *P* (T<=t)* bi-caudal |
|---|---|---|---|---|---|
| NG | WA (%) | 60.72 | 16.94 | 27.9 | *0.027 |
| WG | WA (%) | 53.01 | 11.71 | 22.1 | |

**P* = .05, the difference is significant at the 5% significance level*

**Table 4. Results of RE and IR for the blockboards**

| Treatment | Factor | Mean | Standard deviation | Coefficient of variation (%) |
|---|---|---|---|---|
| NG | RE (%) | 8.78 | 1.30 | 14.80 |
| | IR (%) | 1.82 | 0.81 | 44.60 |
| WG | RE (%) | 8.57 | 1.81 | 21.13 |
| | IR (%) | 2.41 | 1.70 | 70.55 |

**Table 5. *P* values obtained by relating the two treatments**

| Teste T | RE | IR |
|---|---|---|
| *P*(T<=t)bi-caudal | 0.51 | *0.05 |

**P* = .05, the difference is significant at the 5% significance level*

**Table 6. Average values obtained in static bending for the blockboards**

| Treatment | Factor | Mean (MPa) | Standard deviation | Coefficient of variation (%) |
|---|---|---|---|---|
| NG // | MOE | 9,324 | 2,818 | 30.2 |
| | MOR | 58.21 | 13.32 | 22.8 |
| | SPL | 28.71 | 7.12 | 24.8 |
| NG⊥ | MOE | 2,625 | 398 | 15.1 |
| | MOR | 22.6 | 2.07 | 9.2 |
| | SPL | 10.43 | 1.36 | 13.1 |
| WG // | MOE | 7,947 | 1,836 | 23.1 |
| | MOR | 54.95 | 16.27 | 30.0 |
| | SPL | 28.36 | 6.85 | 24.2 |
| WG⊥ | MOE | 2,443 | 485 | 19.8 |
| | MOR | 19.00 | 3.7 | 19.6 |
| | SPL | 9.84 | 1.9 | 19.6 |

*NG // - no edge gluing the battens, parallel to the fibers; NG⊥ - no edge gluing the battens, perpendicular to the fibers; WG // - with battens edge gluing, parallel to the fibers; WG⊥ - with battens edge gluing, perpendicular to the fibers*

The elasticity module is an intrinsic property of materials, which is dependent on the chemical composition, microstructure and defects such as pores and fissures. Module or tension of rupture is the maximum load supported by a beam until breakage. In this experiment, the comparison was made with respect to the direction of the fibers, i.e., comparing the treatments for parallel and perpendicular to the fibers test specimens separately.

The parallel specimens achieved much higher values and treatment NG presented higher MOE and MOR when compared to WG treatment, both in parallel and in the perpendicular directions. To conclude whether the differences are significant or not, the t test was performed comparing direction wise (parallel with parallel and perpendicular with perpendicular), as shown in Table 7.

A comparison between MOE and SPL does not result in significant differences. Only MOR of panels in the perpendicular direction showed significant difference ($P$=.05), which means that treatment NG had significantly higher MOR value than WG. Cabral [16] found mean values of 47.40 MPa for MOR and 5,765.30 MPa for MOE of parallel and 18.56 and 957.69 MPa for MOR and MOE, respectively, for perpendicular to the fibers direction. These results were obtained for a multilaminated panel of *Pinus Taeda*. It can be inferred from these results that the blockboard panel studied achieved better values of strength and stiffness.

#### 3.2.2 Dynamic analysis of elasticity module - stress wave timer

It is important to compare the dynamic ($MOE_d$) with the static MOE, comparing values obtained in the non-destructive testing (Stress Wave) with the destructive, to observe the possibility estimating MOE without destructing of the material. It can be seen in Figs. 4 and 5, the relationship between the $MOE_d$ and MOE for parallel and perpendicular specimens.

It can be observed in this Fig. 4, the relationship between the two variables was reasonable, that is, the equation to determine the MOE from the $MOE_d$ in this case, will estimate values similar to real.

In the case (Fig. 5) of perpendicular direction, the correlation between $MOE_d$ and MOE was low, but still acceptable for estimating non-destructively MOE.

**Table 7. Values of t test comparing the specimens parallel, perpendicular, and all together**

| ***P*(T<=t) bi-caudal** | **MOE** | **MOR** | **SPL** |
|---|---|---|---|
| NG // and WG // | 0.23 | 0.95 | 0.89 |
| NG ⊥ and WG ⊥ | 0.39 | 0.02* | 0.46 |
| NG and WG | 0.31 | 0.48 | 0.99 |

**P = .05, the difference is significant at the 5% significance level*

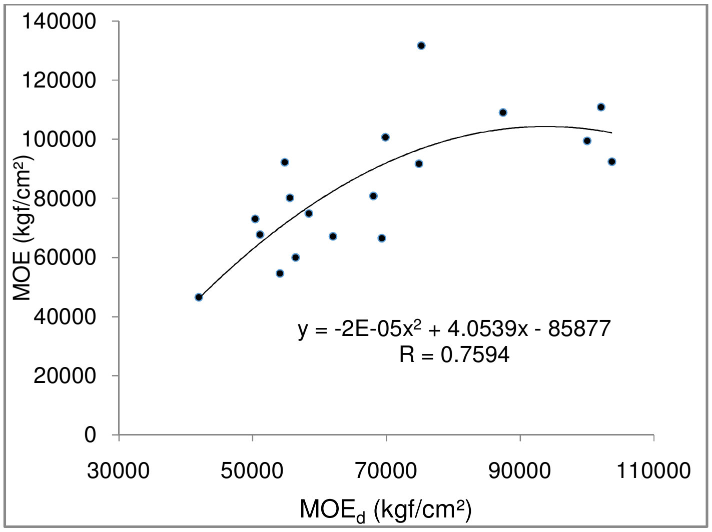


**Fig. 4. Regression between the MOEd and MOE parallel to the fibers**

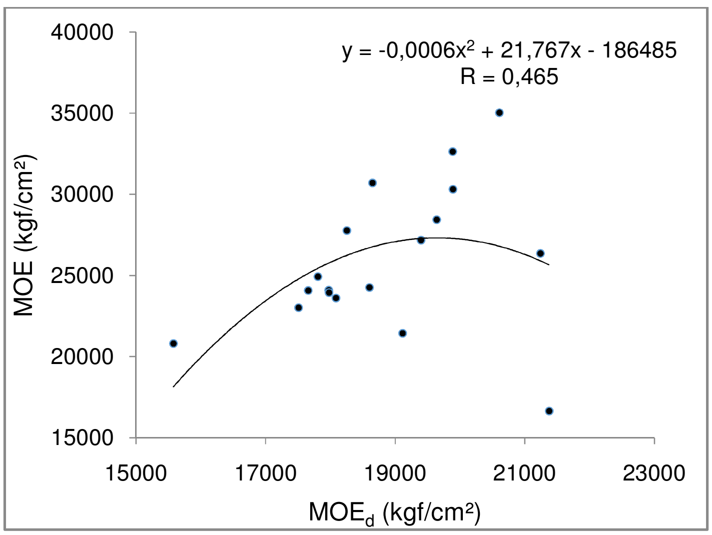


**Fig. 5. Regression between the MOEd and MOE perpendicular to the fibers**

### 3.2.3 Resistance to shear in the glueline

This experiment aims to evaluate the glueline quality and determine the more appropriate use for the blockboard, that is, suitable as indoor use, which is evaluated in the dry test, intermediate, evaluated in the wet test, or outdoors, evaluated in the boiling test [2]. Considering that the phenol formaldehyde adhesive used is suitable for outdoors use, it was conducted the boiling test. The standard EN 314-2 [14], specifies the minimum tension resistance required in bonding and wood failure in the glueline, according to the test performed. Values are shown in Table 8.

**Table 8. Bonding requirements (average values) for plywood panels**

| Shear strength in the glueline | |
|---|---|
| **Shear strength (TR) – kgf/cm² e (MPa)** | **Wood failure (%)** |
| 2.0 (0.2) ≤ TR < 4.1 (0.4) | ≥ 80 |
| 4.1 (0.4) ≤ TR < 6.1 (0.6) | ≥ 60 |
| 6.1 (0.6) ≤ TR < 10.2 (1.0) | ≥ 40 |
| 10.2 (1.0) ≤ TR | No requirements |

*Source: EN 314-2 [16] standard*

The mean shear strength (TR) and the average percent of wood failure are shown in Table 9.

**Table 9. Results of shear strength and wood failure for the blockboards**

| Treatment | Factor | Mean | Standard deviation | Coefficient of variation (%) |
|---|---|---|---|---|
| NG | TRC (MPa) | 3.3 | 0.6 | 17.6 |
| | Failure (%) | 47.7 | 36.6 | 76.8 |
| WG | TRC (MPa) | 3.9 | 0.6 | 16.3 |
| | Failure (%) | 34.3 | 36.9 | 107.6 |

Comparing the results obtained and the values required by the standard, both treatments NG and WG are within the specified standard values either for the shear strength or wood failure. Silva [2], cited by [16], found an average shear strength of 1.73 MPa for plywood of *Pinus* sp. bonded with phenol formaldehyde adhesive. Using plywood produced from construction wastes, [2] found shear strength of 0.20 and 0.19 for PU and PVA adhesives, respectively. Working with plywood of *Pinus* sp. bonded with phenol-formaldehyde adhesive, [16] reported average values of 0.4 MPa.

To verify the statistical differences, the t test was performed on the samples, the result is shown in Table 10.

**Table 10. t Test for the shear strength and wood failure**

| **t Test** | ***P* (T<=t)* bi-caudal** |
|---|---|
| Shear strength | *0.002 |
| Wood failure | 0.287 |

**P* = .05, the difference is significant at the 5% significance level*

Only shear strength was significant according to the *P* value, even though the results were very close. The WG treatment achieved higher shear strength than the NG treatment. It is explained by the bonding of edge battens with PVA glue, as this procedure can give more strength to the panel.

## 4. CONCLUSIONS

According to results of this study it can be concluded that:

- Physical properties of moisture content, density and recovery in thickness of the blockboards were not affected by the treatments (with or without edge gluing the battens) and are within the standard requirements. As for water absorption, the WG treatment showed better results. Treatment WG had higher thickness swelling and more recovery in thickness than NG;
- Mechanical properties of MOE and SPL, either in parallel and perpendicular to fiber directions and MOR in parallel, were also not affected by the treatments (NG or WG) and are within the standard requirements. Only MOR in the perpendicular direction, even though not far apart, showed significant difference and treatment NG was higher than WG. Pertaining to shear strength the higher value was obtained for treatment WG, but also very close. Stress Wave Timer test may be a potential tool for estimating the MOE of both treatments;
- The results obtained were satisfactory for both treatments and used material from construction waste, therefore, of low cost.
- It is important to observe that bonding or not the battens in the core panel produced no effect altogether, meaning that one less processing results in cut of costs in production;
- It is recommended an analysis of the economic viability of producing panels with the waste wood.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. ABRELPE. Brazilian Association of Public Cleaning and Special Waste Companies. Overview of Solid Waste in Brazil 2014. 2014;120.
2. Silva IS. Production and characterization of plywood (blockboard) from wood residues of the construction industry. Course Conclusion Project, Faculty of Technology, Dep. of Forest Engineering, University of Brasília, Brasília. 2013;30.
3. Gonçalves JE, Sartori MMP, León AL. Energy from briquettes produced from waste from municipal solid waste and from

*Eucalyptus grandis* wood. R. Bras. Eng. Agríc. Environmental. 2009;13(5):657-661.
4. Costa EM. *Eucalyptus* wood in the furniture industry. In: Seminar on wood processing and utilization of reforestation, Curitiba. Anais, Curitiba: ABPM / SBS; 1996.
5. Teixeira DE, Silva IS. Recycling wood waste from construction sites: Part 1: Manufacture and characterization of blockboard. In: Proceedings of the 59th International Convention of Society of Wood Science and Technology, Curitiba, Brazil. 2016;47-59.
6. Iwakiri S. Wood panels. Curitiba: FUPEF, 1998. (FUPEF: Didactic Series, 1/98). 1998;128.
7. Mendes LM, Albuquerque CEC de, Iwakiri S. Plywood blockboards: Wood quality, aspects of production and use of waste. Editora UFLA.br; 1999.
8. ABNT. Brazilian Association of Technical Standards NBR 9484: Plywood: Determination of moisture content. Rio de Janeiro. 2011;2.
9. ABNT. Brazilian Association of Technical Standards NBR 9485: Plywood: Determination of apparent specific mass. Rio de Janeiro. 2011;3.
10. ABNT. Brazilian Association of Technical Standards NBR 9486: Plywood: Determination of water absorption. Rio de Janeiro. 2011;3.
11. ABNT. Brazilian Association of Technical Standards NBR 9535: Plywood: Determination of swelling. Rio de Janeiro. 2011;9.
12. European Standards. EN 310:1993. Wood-based panels – determination of modulus of elasticity in bending and of bending strength. Unided Kingdom. 1993;13.
13. European Standards. EN 314-1: Plywood – bonding quality. Part 1: Test methods. Unided Kingdom. 2004;23.
14. European Standards. EN 314-2: Plywood – bonding quality. Part 2: Requirements. Unided Kingdom. 1993;12.
15. ABNT. Brazilian Association of Technical Standards NBR 9434: Plywood: Plywood - bonding quality - Part 1: Test methods. Rio de Janeiro. 2011;9.
16. Cabral BM. Quality of *Pinus taeda* plywood panels produced by industries in the Irati/PR region. Dissertation (Forest Engineer Degree) - Agrarian and Environmental Sciences Sector, State University of the Center-West - UNICENTRO, Irati. 2011;43.



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