

Addition of Impregnated Paper Residue to Produce MDP Wood Panel: example of solid waste recycling

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Abstract Brazilian market for wood panels is expanding. Among the types of produced panels, particleboards deserve, being MDP panel the main product. MDP means Medium Density Particleboard that is a lignocellulosic composite made with matrix of synthetic adhesive (urea formaldehyde resin) and reinforcement phase of particles of wood, and composed of three layers. This product can be marketed coated, being the Low Pressure (LP) coating the most widely used. The LP coating is defined as a special impregnated paper with melamine resin, fused to the wood panel by the action of heat and pressure. During production activities of the MDP with LP coating, impregnated paper waste are generated, which are commonly disposed in landfills, generating costs of transport and disposal of waste. However, this residue can be better applied. In order to promote better use of that waste, this study aims to evaluate the technical feasibility of incorporating the impregnated paper waste as an aggregate in the inner layer of the MDP. Other expected benefit from this proposal is the decrease of costs production because of optimization for wood consumption. For the new composite suggested a technical feasibility has been conducted by tests performed according to Brazilian standard NBR 14810/2006. To this end, physical tests were performed to determine the density of the panel, swelling in thickness, and water absorption. Also, mechanical tests were conducted of perpendicular tensile (internal adhesion) and static bending of specimens. To prepare the studied panel, were collected impregnated paper waste, and mixed them with the wood particles with resin, in proportions of 0% (condition 1), 4% (condition 2), 8% (condition 3) and 12% (condition 4), based on wood particles weight. It was checked that insertion of impregnated paper waste in the inner layer of MDP panel hasn't affected the physical and mechanical properties in comparison with the conventional product. All the results were in line with the NBR 14810 for conditions 1, 2 and 3. Some problems were noted to condition 4, where part of the results were not in consonance with the Brazilian standard for particleboards. These conclusions were also engaged in the results of statistical variance analysis performed. However, the recycling proposal of utilization the impregnated paper waste is technically feasible, contributing favorably to the rational use of raw materials, reducing operational costs with waste treatment and a greater level of environmental sustainability within the industry.

Keywords Wood Panel, MDP, Particleboard, Impregnated Paper, Recycling

1. Introduction

The wood panel industry in Brazil is currently the 3rd largest forest-based industrial sector[1]. In world terms, Brazil is among the ten largest producers of wood panels[2].

Considering the different classes for wood panels, one important class is the reconstituted panels. These are made with reconstituted wood particles or fibers, and the main ended products are: Medium Density Particleboard (MDP), Oriented Strand Board (OSB), Medium Density Fiberboard(MDF), Hard Density Fiberboard (HDF) and insulating panels[2, 3]. This class also comprises others

products of lower commercial expression, such as wood-cement panels, wood-plastic and others lignocellulosic materials.

The reconstituted panels can be supplied in different dimensions and finishing types. About finishing, the panels can be sold raw (fresh) or coated. When coated, the coating process can be made by the panels companies. The panels can be coated on one side or on both sides, in patterns like wood grain or unicolor. Below are listed the main types of coating models to wood panels, according to Iwakiri[3], Mattos et al.[4] and Biazus et al.[2].

- Laminated of low pressure (LP): foil with weight range of 70-180 g / m², impregnated with melamine resin fused on the panel by the action of heat and pressure. Nowadays, this is recognized as the main type of coating model adopted;

- Finish Foil (FF): foil with weight range of 30-60 g / m², glued on the panel using resin and catalyst, combined with

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temperature action;

- Others: high pressure laminated (HP), natural wood laminate, plastic laminate, lacquer, painting, printing, etc. Mattos *et al.*[4] claim that the MDP is among the top wood panels consumed. Biazus *et al.*[2] cited that this product is the reconstituted wood panel more produced and more consumed in the world, and its application focuses on the furniture market, for the production of residential and office furniture in straight lines (tabletops, side cabinets, shelves and dividers).

MDP refers to medium density particleboard, a derived product from wood[5-10]. The MDP is a panel classified as composite material or just composite. Callister[11] considers a composite material like "any multiphased material which exhibits a significant proportion of the properties of both phases that constitute it, so that is obtained a better combination of properties." About the phases making up the composite, there are generally only two. One is called matrix, which is continuous and surrounds the other phase that is called the dispersed phase or reinforcement phase[11]. MDP consists of a synthetic polymeric adhesive as the matrix phase, and the reinforcing phase is made of wood particles which are combined with the application of heat and pressure to consolidate and give rise to the panel. Being made from natural vegetable fibers, the MDP is also classified as a lignocellulosic composite.

Brazilian Association of Wood Panels – ABIPA[12] cites that the MDP is made of three layers, where the two surface layers consist of particles with smaller dimensions, and the inner layer comprises larger particles.

To produce MDP is used wood from planted forests, particularly from Eucalyptus and Pinus plantations. The synthetic adhesive applied to manufacture the panel has like basic components the thermosetting resin (generally, urea formaldehyde), the wax emulsion and the catalyst (chloride / ammonium sulfate)[3; 13].

Michelon[14] studying an Brazilian company that produces the MDP, found during the finishing process for the laminated LP model, a considerable amount of impregnated paper with melaminic resin is generated, and to control this waste generation is difficult, because some losses are inevitable, considering the currently technology available. The usual treatment for this residue is the final disposal in landfills. However, this residue could be quantified and analyzed aiming to check a possible better alternative of destination strategy.

As a better strategy to use the impregnated paper waste (IPW), this study evaluated the possibility of its reuse as secondary material for the production of the MDP. This residue was added on the inner of MDP in different proportions in order to analyze the physical-mechanical properties of this new type of product, checking its technical feasibility.

The main benefits related to the idea of recycling the IPW during the production of the MDP are:

- Economic advantages: reducing costs of disposal and transportation waste to the companies;

- Environmental improvements: by recycling the residue within the production process.

In the MDP companies efforts are constantly taken to reduce the IPW generation. But the suggested strategy of recycling this waste as secondary material to produce the MDP would be a good way to eliminate it, if there is a high incidence of its generation. So, it's important to study the technical performance of this new composite material, the MDP with impregnated paper waste addition.

Thus, this paper aims to study the physical-mechanical properties of the MDP made from Eucalyptus sp wood species, produced with IPW incorporation according to their amount of particles in the inner layer. The physical-mechanical properties of the manufactured panel were performed in consonance with the relevant standards to the topic, and discussed in terms of checking the technical performance of this new product proposed.

2. Materials and Methods

The impregnated paper can be defined as a decorative laminate, containing in its composition a Kraft paper as the basic component, being impregnated with melamine and/or urea resins mixed, and also with additives intended to improve certain properties of the coated panel[14, 15].

According to Winkler *et al.* al[15] the impregnated paper contains a large amount of resin in its constitution, representing about 60%, and the Kraft paper accounting for approximately 40% of the constitution.

For Winkler *et al.*[15] and Minholi[16], about the resin component applied in the impregnated paper, its main elements are:

Aminic resins: are condensates formed when carbonyl compounds (like formaldehyde) react with compounds containing amino, amino or amide groups (such as urea or melamine), with release of water. Among the amidic resins available, the melamine resins are mainly used for the impregnation process, because they give better properties, such as mechanical strength to risk and abrasion, greater flexibility, lower incidence of spots in the coating, lower hygroscopicity, etc. Another option is the urea resin that presents lower cost than the melamine resin, but is not as efficiently technically;

Catalyst: are substances capable of controlling the speed of reaction according times economically viable for manufacturing. Without these compounds to occur the polymerization of resin, the impregnation speeds would be very low, becoming the impregnation process impracticable;

Additives: are substances added to the impregnating resin to give to the final product the apparent and technological quality desired. They can be classified as plasticizer, desmolding agent, humectants, anti-blocking, antifoam, and pigment.

The composite manufacturing:

To evaluate the technical performance of the MDP

modified, with IPW applied like secondary material, were prepared 4 different test conditions. The panels were made of 400×400mm of dimensions and 15mm of thickness, as exposed in Table 1, that also shows the compositions tested in the inner layer.

The insertion of IPW occurred only in the inner layer of the panel, and the surface layers remained with 100% of wood particles from *Eucalyptus* sp.

Table 1. Different compositions tested in the inner layer of the material composite evaluated

Test conditions	Wood particles (%)	IPW (%)
1	100	0
2	96	4
3	92	8
4	88	12

The adhesive used to prepare the panels was the urea-formaldehyde resin, with other chemicals such as wax emulsion, water and catalyst (ammonium sulfate). The solids content of urea-formaldehyde resin was 66%, wax 60% and catalyst 53%.

The IPW were collected directly from the waste containers of a producer of the MDP in Brazil, who donated these residues for the conclusion of the present study. The residues were then mixed with the wood particles of inner layer.

The IPW after being collected, they were processed into smaller particles and classified as shown in Fig. 1. According to the figure, step 1 shows a waste container with IPW; in step 2 the IPW collected is prepared using manual scissors to reduce their dimensions for next processing in a domestic blender in step 3. The IPW processed in small particles from step 3 are shown in step 4. And the step 5 shows the result of the IPW classified using sieves of 6.53 mm/mm of particle size.

Then, were made the wood panels mixing the IPW particles in the inner layer of the MDP, considering the 4 conditions specified in Table 1. Following, Fig. 2 shows a mattress with the wooden chips and the IPW particles in the inner layer of the MDP, before the hot pressing process. Step 1 in Fig. 2 shows a overall view of the mattress before the hot pressing process, and step 2 details the three layers of the MDP, where the IPW particles are located just in the inner layer as recommended in this study.

Later, the panels were cut in order to obtain the samples for the physical tests of water absorption (in 2 hours), thickness swelling (in 2 hours) and density determination; and also for the mechanical tests of perpendicular tensile (internal adhesion) and static bending. All the tests cited were conducted base on the standard NBR14810:3[17] and the results were compared to the requirements of NBR14810:2[18].

The experimental results were statistically evaluated across an analysis of variance using Tukey method with 95% confidence level, by the Minitab r16 software.



Figure 1. Preparation of IPW in particles

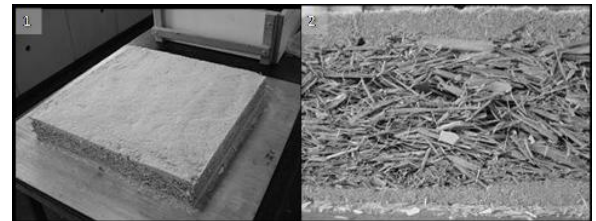


Figure 2. Mattress and details of its three layers

3. Results and Discussions

Tables 2 to 6 summarize the main results of the physical and mechanical properties determined for the samples analyzed. Based on the symbols adopted, “X” is the average result, “s” is the standard deviation, “n” means the number of samples and “CV” is the variation coefficient (%). All results also were statistically analyzed, and different letters with the “X” results, determine average results statistically different at the 95% level of probability.

Table 2. Average density results (kg/m³)

	Test conditions			
	1 (0%)	2 (4%)	3 (8%)	4 (12%)
X	609.00 a	603.20 a	602.00 a	600.00 a
s	15.70	19.60	16.60	14.80
n	10	10	10	10
CV	2.58	3.25	2.76	2.47

Table 3. Average water absorption results (%)

	Test conditions			
	1 (0%)	2 (4%)	3 (8%)	4 (12%)
X	30.00 a	30.88 a	33.55 b	35.44 c
s	3.7	3.80	5.20	4.20
n	4	4	4	4
CV	12.33	12.34	15.52	11.86

Table 4. Average thickness swelling results (%)

	Test conditions			
	1 (0%)	2 (4%)	3 (8%)	4 (12%)
X	11.7 a	11.02 a	11.20 a	12.80 b
s	0.50	1.00	0.70	0.8
n	4	4	4	4
CV	4.27	13.33	6.25	6.25

Table 5. Average perpendicular tensile results (MPa)

	Test conditions			
	1 (0%)	2 (4%)	3 (8%)	4 (12%)
X	0.52 a	0.55 ab	0.53 ab	0.50 b
s	0.050	0.045	0.044	0.060
n	6	6	6	6
CV	9.61	8.18	8.30	12.00

Table 6. Average static bending results (MPa)

	Test conditions			
	1 (0%)	2 (4%)	3 (8%)	4 (12%)
X	16.20 a	16.20 a	16.12 ab	15.93 b
s	1.67	2.63	1.49	2.14
n	3	3	3	3
CV	10.31	16.23	9.24	13.43

The most part of results were in line with the NBR14810:2[18]. However, some exceptions were found. Following, the main points are highlighted.

The density results for all conditions were satisfactory, according the range of 551 kg/m³ to 750 kg/m³ suggested by NBR14810:2[18] for medium density wood panels being above the lower limit of the standard. The results showed to be statistically equivalents at 95% of confidence level.

Relative of water absorption, whereas NBR14810:2[18] sets a maximum limit of 35%, only the condition 4 (12% of IPW) were not satisfactory, didn't respecting this limit. All the others conditions were in line with the standard. The statistical results expose conditions 1 and 2 are equivalents, but conditions 3 and 4 are different. So, it suggests that increasing the amount of IPW, higher is the water absorption effect. It happens probably because of problems of adhesion between IPW particles with wood particles and resin, contributing to increasing the higroscopicity of panel. Similar conclusion was checked for the thickness swelling analysis.

It can be concluded that during the thickness swelling tests the most part of values obtained were in consonance with the recommendations of Brazilian standards, being not more than 12%. But, as exception, again, the condition 4 showed superior result. The statistical analysis showed conditions 1, 2 and 3 are equivalents and different of

condition 4.

Table 5 presents the results for the perpendicular tensile tests. It can be noted that all the values were satisfactory when compared to Brazilian standard, which specifies the minimum value of tensile of 0.35 MPa. The statistical results performed suggest conditions 2 and 3 are equivalents to conditions 1 and 4, but these are different from each other. Conditions 1 and 4 being statistically different, it seems that increasing the IPW content in the panel, the results will really decrease.

For static bending tests, as seen in Table 6, only the condition 4 (12% of IPW) didn't meet the values specified by NBR14810:2[18], that establishes a minimum expected value of 16.1 MPa. All others conditions investigated were coherent with the standard. Condition 3 was statistically equivalent to 1, 2 and 4. Conditions 1 and 2 were statistically equivalents, but different comparing to condition 4.

The range 4 to 8% of IPW content showed properties results that satisfied the specifications from NBR14810:2[18]. Just the condition 4, with 12% of IPW showed problems related to water absorption, thickness swelling and static bending. A comprehensive analysis form the statistical analysis performed confirms these claims.

4. Conclusions

It can be concluded that the recycling proposal of utilization the impregnated paper waste, as secondary material to produce the MDP, is technically feasible, especially for condition 2 and 3.

The condition 4, with 12% of IPW showed problems, cause some properties were not satisfactory according the Brazilian standards and the statistical variance analysis. It indicates that there is a limit where it's possible to add the IPW without to compromise the technical performance of the MDP. However, conditions 2 and 3 showed satisfactory results comparing to condition 1, the Brazilian standard and with the statistical analysis conclusions.

Analyzing the results obtained, this alternative of waste recovery, contributes favorably to a rational use of raw materials (especially, reducing the wood consumption), and a greater level of environmental sustainability within the industry.

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