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USE OF RESIDUES FROM THE FURNITURE INDUSTRY AS A CONSTRUCTION MATERIAL: AN INVENTORY AND PROPOSAL FOR THE FURNITURE HUB OF UBÁ, MG, BRAZIL

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RESUMO
A utilização da madeira em construções, como material resistente, durável e sustentável, é conhecida desde tempos remotos. Para fins de composição arquitetônica, desempenho, custo e manutenção, a madeira e seus derivados coexistem com outros distintos materiais nas partes integrantes de uma habitação. Uma opção interessante para empregar derivados da madeira em habitações é aplicar painéis recompostos com resíduos de madeira oriundos de processos das indústrias de móveis de madeira. Em muitos casos, a disposição dos resíduos gerados dessa matéria-prima no meio ambiente se faz sem tratamento algum, conforme identificado no presente estudo em indústrias de móveis do polo moveleiro de Ubá, Minas Gerais, Brasil. Tal contexto motivou uma pesquisa para verificação do potencial de geração de resíduos neste polo moveleiro, com o objetivo de utilizá-los na produção de painéis recompostos de madeira como partes constituintes de uma habitação. Primeiramente, foram identificadas na literatura possibilidades para substituir a madeira maciça e a alvenaria convencional por painéis recompostos de madeira. A seguir, foi apresentada uma análise do porte da geração de resíduos de madeira das empresas da área de estudo, o que permitiu estimar o potencial de resíduos de madeira gerados no polo moveleiro. A estimativa indicou possibilidade técnica de aproveitamento desses resíduos para a produção regional de painéis recompostos, aplicáveis e incorporáveis na construção de habitações.

PALAVRAS-CHAVE: Resíduos de madeira, painéis de madeira, habitação.

ABSTRACT
As a strong, durable and sustainable material, wood has been used in buildings since ancient times. For architectural composition, performance, cost and maintenance purposes, wood and its derivatives coexist with other distinct materials as integrant parts of a dwelling. An interesting option to use wood derivatives in housing applications is to reuse panels recomposed with wood residues from the wood furniture industries. Many times, these residues have been discarded in the environment without any treatment, as identified in the present study for industries of the furniture hub of Ubá, Minas Gerais, Brazil. This context motivated the development of a research to verify the potential generation of residues in this furniture hub, in order to use them in the production of recomposed wooden panels that are constituent parts of a house. Firstly, the possibilities for replacing solid wood and conventional masonry with recomposed wood panels were identified in the literature. In addition, an analysis of the amount of wood residues generation of the companies was carried out, allowing an estimation for the Ubá's furniture hub. The estimate suggested the technical feasibility of using these residues in the regional production of recomposed wooden panels for application in dwellings.

KEYWORDS: Wood residues, wood panels, dwelling.

INTRODUCTION

The history and development of using wood as a structural component, since antiquity, is mainly associated with the construction of housing, bridges, war machines and boats. As a construction material, wood has excellent attributes such as high strength and easy handling for the manufacture of components, in addition to aesthetic characteristics (Augustin, 2008).

Industrial processes that use wood as a raw material in their production system have generated large amounts of waste, generally disposed of in the environment without any treatment. In addition to raw material waste, wood residues generated in the furniture industries represent potential environmental impacts, when discarded in inappropriate places

or incinerated, as they pollute the environment due to their component materials (WEBER, 2011); in addition, excess or accumulation of waste, regardless of its characteristics, can become a source of fire (LACOMBE, 2015).

Solid wood is a resistant and durable material. It can present a longer lifespan since correctly used and with the necessary treatments (REMADE, 2004). However, there are conditions in which its use in homes can be replaced by composite wood panels incorporating the aforementioned waste, representing savings. These panels are products obtained by gluing particles, fibers or wood veneers, using specific adhesives, pressure and temperature (AITIM, 2011). One of the objectives of using panels is to explore low-density wood, small dimensions or waste resulting from this process (LOPEZ; PAES; GONÇALVES, 2016).

Wander (2001) and Hüeblin (2000, p.130 apud CASSILHA et al., 2004) distinguish and classify the three main types of wood wastes generated in the furniture industries.

- **Sawdust** - residue originated from the operation of saws (dimensions of 0.5 to 2.5 mm). It is found in several types of industries and can be dry or wet. It reaches up to 12% of the total volume of raw material.

- **Brush -** residue generated by the planers in the sawmill/processing and beneficiation facilities (dimensions higher than 2.5 mm), which can reach 20% of the total volume of raw material. In industries, it is found exclusively in the dry state, as some industries acquire the already transformed wood and process it into components for furniture, frames, floors and ceilings;

- **Chip** - larger residue (particles with dimensions of 50 mm × 20 mm, generally resulting from the use of chippers), generated in all types of industries, consisting of shorelines, shavings, trimmings, bark and others; in sawmills and rolling mills, it can reach 50% of the total volume of raw material.

Alternatives for some materials discarded from industrial processes are (i) reuse when products are used again for the same purpose or destined for a second use, extending the life of the original product and reducing waste; (ii) recycling, which involves collecting waste and processing it into new products; and (iii) discarding, when there is no possibility of any of the previous solutions (VESILIND; MORGAN, 2011 apud VIOLA, 2012).

In civil construction, wooden panels provide excellent functional, constructive and economical solutions, competing with traditional sealing systems. The panels can be used both for external sealing and for internal subdivision of buildings, either by reducing construction loads or facilitating transport and workability at work (SUENAGA; BITTENCOURT; TERNI, 2002 apud SANTOS; AGUILAR, 2007).

As a possibility of application in different parts of wooden constructions, such as vertical fences and horizontal fences, composite wood panels have the advantage of rationalizing and reducing the use of non-renewable materials in conventional housing. Its use in components can reduce the cost of wood, cutting pieces, waste generation, in addition to increasing the use of industrial waste minimizing environmental impacts (WEBER, 2011).

Wood has great economic importance due to its wide use in the civil construction, transport, furniture and prefabricated components industries due to plasticity in the design, speed of assembly and durability (WEBER, 2011). From the point of view of business and public agencies linked to the protection and defense of the environment, recycling and reuse of wood waste generated by the furniture industry are ways attractive for solving waste management problems (ROCCA et al., 1993 apud TÔRRES FILHO, 2005). The following aspects are relevant to making panels feasible in housing: quality of components made from wood waste; durability; comfort; structural and patrimonial security; cost for its insertion; and maintenance.

Ubá is a municipality in the Zona da Mata region of the Minas Gerais State, Brazil, with about 115 thousand inhabitants (IBGE, 2019). Ubá stands out for its large number of furniture factories. The furniture hub of Ubá is among the main ones in Brazil, employing 330,000 thousand people, producing 11.8 million pieces, and with revenues of R$2.9 billion (ABIMÓVEL, 2014). Regionally, it is also mandatory to know the total wood waste generated by the Ubá's furniture hub industries since it is a potential contributor to panels' manufacture. In order to use the residues from the Ubá's furniture industry as a construction material, it is necessary to know the parts of a building in which they can be applied, depending on the exposure conditions and the characteristics of the panels currently on the market.

OBJECTIVES

This work aimed to elaborate an inventory for raw materials consumption and wood waste generation in the furniture industries of the Ubá furniture hub industries, in addition to identify the potential reuse of the waste materials for production of wood composite panels applicable in constituent parts of dwellings.

METHODOLOGY

At first, promising applications of wood residues in the construction sector were investigated. A bibliographic research was carried out to identify the possibilities for applying panels containing wood waste as constituent parts of a dwelling. This literature review was conducted on composite wooden panels containing wood waste and composite panels in housing. The following materials were consulted: theses, dissertations, journals, standards, books and other technical publications.

After that, a survey of data related to waste generation in Ubá's furniture hub industries was carried out. Among the 315 active companies in this hub in 2019, small and medium-sized companies focused on producing wooden residential furniture predominate. A total of 86 companies were associated with the Intermunicipal Union (INTERSIND) in 2019. As a member of the Brazilian Furniture Industry Association (ABIMÓVEL), INTERSIND detects and directs new strategies to enhance the performance of industries on the national scene. Data from Abimóvel, Intersind and some companies were obtained and analyzed.

RESULTS

In order to use the residues from the Ubá's furniture industry as a construction material, it is necessary to know the parts of a building in which they could be applied, depending on the exposure conditions and the characteristics of the panels currently on the market. Previous research was compiled to identify the technical feasibility to combine the wood wastes generated in manufacturing processes of Ubá's furniture industries with resin, in order to produce various types of recomposed wood panels, such as MDF, MDP and OSB, as well as WPC.

For example, Koch (2012) mentions that one of the uses of these residues is to serve as raw material for the manufacture of recomposed wood panels or the generation of energy. Table 1 shows that composite wood panels can generate a wide range of products for the building sector, presenting high durability characteristics. Their properties are influenced by the compositions of the raw materials (types of resins) and production processes (layers, pressure, temperature), according to previous literature [Boumbimba et al. (2014); Yemele et al. (2010); Jam and Behravesh (2007); Klyosov (2007); Youngquist (2013); Torquato et al. (2010); Torquato (2008); IPT (2009); Santos and Aguilar (2007); Setubal (2009); Molina, Career and Calil Junior (2009)].

Table 1. Proposal for application of wood wastes in recomposed wood panels.

Panel	Characteristic	Application
MDF	As a finishing material, it can be painted or varnished; it has a uniform, flat and rounded surface; Due to the high density, it can be used outdoors and on wet surfaces; It can be turned, notched and drilled.	Floor, skirting, cushion and door jamb, machined door, coating, wall, frame, showcases, turned part.
MDP	Greater bending strength, warping and pullout of screws; greater dimensional stability; less moisture absorption.	Internal use, in partitions and wall coverings.
OSB	Durability; workability – easy to laminate; absence of nodes; impact strength; insulating properties; very low void ratio. Better mechanical and dimensional properties due to the alignment of the chips in the parallel and perpendicular direction of the panels; use less noble raw material for its production and replaces plywood with efficiency and lower cost; good dimensional stability and moisture resistance gives the panel great durability and resistance to biological attacks.	Linings; walls; stands; decorative panels; floors; sidings; partitions; disposable forms for concrete and platforms; rustic cottages; frames; structural support panels; insulating structural panels (foam core) and web for "I" beams; mezzanines; raised floors.

Panel	Characteristic	Application
WPC	Durability - immune to fungi attacks, rodents, termites and other insects. It has mechanical strength and recyclability, resistance to humidity and cracks, corrosion, fire, rain, dust, sea air; does not show cracks under the action of sun or rain; resists high temperature and impact; High nail fixation, does not oxidize under the action of screws; does not require varnishing; does not generate splinters; provides thermal comfort; waterproof; Good surface finish; appearance to common wood; does not require special treatments; does not require environmental certification; It can be sawn, planed, stapled, glued and welded, dyed, painted, drilled, screwed, nailed.	Upright, sleepers, posts, pallets, decks, piers, crossarms, fences, benches, trash cans, plates, playgrounds, frames, frames and frame stops, floors, skirting boards, linings, stairs, facades, pergolas, brises, coatings, benches, washrooms.

Corrêa, Duarte and Abreu (2016) pointed out that despite the representativeness of the furniture sector in the national economy and the number of companies in this sector, there are few initiatives of waste management programs or some type of reuse. Boyle and Baetz (1998) emphasized that to successfully implement a waste management system in an industry, recycling and reuse must be prioritized, minimizing costs and environmental impacts.

Almeida, Logsdon and Jesus (2011) stated that the increasing consumption and inadequate exploitation of Brazilian forests indicate the need to produce panels using wood residues. A study carried out by Blanchet, Cloutier and Riedl (2000) showed that producing composite wood panels with pine residue is technically feasible and can be used indoors. Alencar and Moura (2014) stated that the panels can be formed with different wood species, which can increase or decrease their mechanical strength, depending on the characteristics of the species. In this sense, eucalyptus (*Eucalyptus*) and pine (*Pinus elliottii*) have potential technical feasibility, as these materials are widely used in the micro-region of the furniture industry hub of Ubá.

Considering the promising application of wood wastes in the civil construction sector, an analysis of the amount of wood residues generated by the Ubá's companies was carried out. A total of sixteen companies of the Ubá's furniture hub provided data on the amount of raw material purchased and the types of wood waste generated from the industrial processes. Solid wood (eucalyptus and pine), MDF and MDP panels were identified as the most used materials in the manufacturing processes. The two most cited types of wood waste in these companies were wood chips and sawdust.

Table 2 shows the quantities of purchased raw material and the total waste in cubic meters, being converted to kilograms for analysis. The panels are purchased in square meters, as their thickness varies for each product type. The data were based on the purchase to meet production demand and waste generation within one month, the most recent being on the date the survey was carried out (September to November 2018).

Table 2. Raw material acquired and waste generated.

Company	Raw material	Quantity acquired		Type of residue	Waste generated		Waste percentage
		Volume (m^3)	Mass (kg)		Volume (m^3)	Mass (kg)	
A	Solid wood	496	347,200	Chips	80	18,640	24.4
	Panels	0	0	Sawdust	240	66,000	
	Total	496	347,200	Total	320	84,640	
B	Solid wood	7	4,900	Chips	0	0	23.2
	Panels	3	2,223	Sawdust	6	1,650	
	Total	10	7,123	Total	6	1,650	
C	Solid wood	25	17,500	Chips	45	10,485	5.1
	Panels	550	401,352	Sawdust	40	11,000	

	Total	575	418,852	Total	85	21,485	
E	Solid wood	0	0	Chips	25	5,825	1.3
	Panels	1,300	963,144	Sawdust	23	6,325	
	Total	1,300	963,144	Total	48	12,150	
F	Solid wood	25	17,500	Chips	15	3,495	2.6
	Panels	475	333,522	Sawdust	20	5,500	
	Total	500	351,022	Total	35	8,995	
G	Solid wood	38	26,250	Chips	20	4,660	21.1
	Panels	31	21,920	Sawdust	20	5,500	
	Total	69	48,170	Total	50	10,160	
H	Solid wood	0	0	Chips	7	1,631	1.6
	Panels	270	190,104	Sawdust	5	1,375	
	Total	270	190,104	Total	12	3,006	
I	Solid wood	35	24,500	Chips	30	6,990	4.7
	Panels	335	242,880	Sawdust	20	5,500	
	Total	370	267,380	Total	50	12,490	
J	Solid wood	100	70,000	Chips	65	15,029	31.7
	Panels	0	0	Sawdust	26	7,150	
	Total	100	70,000	Total	91	22,179	
K	Solid wood	15	10,500	Chips	20	4660	47.0
	Panels	15	11,113	Sawdust	20	5500	
	Total	30	21,613	Total	40	10,160	
L	Solid wood	60	42,000	Chips	12	2,796	6.7
	Panels	16	11,854	Sawdust	3	825	
	Total	76	53,854	Total	15	3,621	
M	Solid wood	0	0	Chips	80	18,640	1.5
	Panels	1,800	1,260,000	Sawdust	80	22,000	
	Total	1,800	1,260,000	Total	160	40,640	
N	Solid wood	102	71,400	Chips	15	3,495	8.0
	Panels	18	13,091	Sawdust	12	3,300	
	Total	120	84,491	Total	27	6,795	
O	Solid wood	44	30,625	Chips	0	0	3.1
	Panels	1,207	870,692	Sawdust	100	27,500	
	Total	1,251	901,317	Total	100	27,500	
P	Solid wood	0	0	Chips	46	10,814	1.9
	Panels	814	570,108	Sawdust	0	0	
	Total	814	570,108	Total	46	10,814	
Q	Solid wood	0	0	Chips	1,506	350,898	14.2
	Panels	5,953	4,288,759	Sawdust	937	257,675	
	Total	5,953	4,288,759	Total	2,443	608,573	
Total	Solid wood	947	662,375	Chips	1,966	458,058	9.0

	Panels	12,784	9,180,762	Sawdust	1,552	426,800
	Total	13,731	9,843,137	Total	3,518	884,858

The use of different technologies and manufacturing processes results in waste from wood and panels that make up different lines of products manufactured in the furniture hub of Ubá/MG. In prospection based on the data contained in Table 2, it was found that the amount of each type of wood waste generated, in mass (kg/month), in the form of sawdust, shavings or chips is in the range of 7% to 17% of the raw material purchased (solid wood and panels). Based on this data, Table 3 presents a reference base regarding the potential generation of wood residues in that hub.

Table 3. Potential generation of wood waste in the furniture hub of Ubá/MG.

Company size	Number of companies		Average waste generation (kg/month)		Potential waste generation (Intersind) (kg/month)		Potential waste generation (hub) (kg/month)	
	Intersind	Furniture hub	7% (1)	17% (1)	7% (1)	17% (1)	7% (1)	17% (1)
Large	4	7	129,731	315,062	518,925	1,260,247	908,119	2,205,433
Medium	15	40	29,526	71,705	442,885	1,075,579	1,181,027	2,868,209
Small	27	100	21,463	52,125	579,512	1,407,385	2,146,339	5,212,538
Micro	24	168	4,489	10,902	107,736	261,645	754,154	1,831,517
Total	70	315	185,209	449,794	1,649,059	4,004,856	4,989,640	12,117,697
Reference in m^3/month			258	627	2,300	5,587	6,960	16,904

(1) Percentage of waste generated in the surveyed companies: lowest = 7% and highest = 17%.

The estimate projected in Table 3, resulting from the prospection, indicates that the monthly mass loss of raw material in the furniture hub of Ubá/MG, in the form of wood waste, should fluctuate from 4,972 m^3 or 3,564 t to 16,904 m^3 or 12,117 t. Relevant amount of these residues have been used as fuel for burning or generating energy (e.g., ceramic industries), production of charcoal, or disposal with incineration. It is noteworthy that combustion processes are associated with the release of harmful gases to health and the environment due to the presence of substances with toxicological or carcinogenic potential in the waste.

The dataset suggested the technical feasibility of using wood wastes in the regional production of recomposed wooden panels for application in dwellings. Producing panels composed of recyclable materials in the Ubá furniture hub region and generating a change in the economy of the industries responsible for the generation of these waste materials become a determining factor to benefit the environment, the civil construction and society.

CONCLUSIONS

This work investigated the wood residues generated by furniture industries in the manufacture of composite wood panels, which was found to be an environmental problem associated with the furniture hub of Ubá, Minas Gerais, Brazil. The quantities of purchased raw material and the total waste generated by different companies were obtained.

The manufacture of composite panels for the civil construction sector is an alternative that deserves to be studied and evaluated in technical, economic, commercial, environmental and social terms. The prospection indicates a favorable potential for incorporating recomposed panels with wood residues in dwellings. In addition to the importance of identifying in which parts of the building each component is applied or not, it is imperative to consolidate new alternatives in engineering and architecture regarding building materials and the scenario of development of new technologies. Raw material acquired and waste generated by the furniture hub of Ubá was obtained from different companies. The obtained data indicated the technical feasibility of reusing wood wastes in the regional production of recomposed wooden panels in the construction industry.

Data and information obtained in this research regarding wood waste generated in the furniture hub of Ubá, MG, Brazil, provide an overview of the regional potential, contributing to elaborate integrated actions and public policies for a regional development model. In future works, the present model can also be reproduced and improved in other regions or countries with similar characteristics.

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