ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 18 N° 1 2022
pp. 28-35

RECOVERED WOOD AND BRANCHES FOR FURNITURE DESIGN

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Abstract:
The wood waste and biomass should be considered potential resources that can be transformed in useful added value materials. The paper aims to promote a creative use of branches and wood wastes from demolished buildings in a product design. There were used three types of raw material to manufacture a bedside table: beams, sawn timber and scantlings from demolished house, burnt panels from fireproof test and hazelnut branches. These wood wastes were evaluated regarding the quality, density and moisture content and were transformed into original panels for top plate and extendable plates for a piece of furniture. Urea-formaldehyde and epoxy adhesives were used to manufacture these panels. The processing of solid wood elements and panels to the final dimensions was performed on Festool type machine-tools. A multifunctional bedside table was designed.

Key words: *branches; burnt panels; furniture design; wood waste*

INTRODUCTION

Nowadays we are forced to act to reduce the global warming and to transit towards a low carbon economy. This means to use our resources more efficiently, to reduce wastes, recover and recycle of materials as much as possible (https://ieep.eu/publications/the-cascading-use-of-woody-biomass). The production of residues and wastes is an inevitable part of modern society. Based on Eurostat data, EU-27 produced 60 million of wood waste in 2014, which can be a rich source of a useful raw material for different products (https://www.academia.edu/44490336/).

The use of recycled wood rather than virgin wood can contribute to the sustainable exploitation of forest, and is a challenge to turn the wood wastes into profit by processing them into high value products (Daian and Ozarska 2009). Wood waste might come from harvesting or processing, being known as industrial wood waste, and contains more than 50% wood, and from post-consumer (end-of life wood waste) which account for around 22% of the total market volume wood waste. Of this amount, 9% is directed to industrial purpose and over 12% for energy use (IEA Bioenergy 2019).

Beside energy the other possible destinations of wood waste are recycling in particleboards, repairing, landfill, biodegradation (Fellin 2014). The material recovery from wood waste is more complex and is based on recycling through the production of new materials by cascade use, in order to improve the efficient use of resources and extend overall biomass availability (Besserer *et al*. 2021). Wood secondary resources, including branches, represent 25-32% of the total harvested wood and are directed mostly to fire. Branches especially, could be used in new added value product as alternative to stem wood, for manufacturing small furniture articles (Barbu and Teischnger 2010). Liu, W (2020) showed that there is a potential for wood waste from construction to be used in the product design.

Other designer like Philippe Starck, Frank Gehry, WooJai Lee (https://www.connectionsbyfinsa.com/), consider that recycled materials could be a solution for pieces of furniture which can give an eco-touch to the house. Other designers go farther and confide their concepts to the principle of circular economy, such as Patricia Urquiola who is guided by the principle “form follows fabric”, or Humberto and Fernando Campana who acquire inspiration from nature and the street and apply to their unconventional lamps or chairs (https://www.imm-cologne.com/magazine/future-living/recycling-furniture).

With their creative approach, artists, designers extend the life of wood wastes, or wood thrown from demolition or old furniture, by developing a special niche of reclaimed wood furniture.

OBJECTIVE

The aim of this research is to demonstrate how wood waste can be adapted and transformed into the main material for furniture design. Additionally, the potential of branches and burnt panels as raw material for panels was evaluated, as a way to add value to the rather undervalued waste biomass. The challenge was to obtain from these new raw materials, an original piece of furniture. A bedside table with a drawer was designed. The choice of this piece of furniture was determined first of all by the dimensions of the panels obtained from the recovered materials, and then, from a functional point of view. It was chosen a small piece of furniture that would be easily fit in any space at home, and fulfill both the function of storage and serving coffee.

MATERIAL, METHOD AND EQUIPMENT

A. Raw material

The raw material for the furniture design was provided from three sources:

a. Wood waste from a building demolition;
b. Panels resulted from fireproof test;
c. Branches from pruning.

a. Wood waste from a building demolition

The material came from different assortments of timber obtained from a demolished house (Fig.1).

a. **b.** **c.**

Fig.1.
Raw material came from a demolished house: a - beam; b - sawn timber from framing; c - scantling from the roof.

The wooden pieces were analyzed taking into consideration the following steps:

- Visual quality assessment (presence of defects and biologic attack);
- Macroscopic identification of the wood species;
- Determination of moisture content and density;
- Processing and cutting the pieces at dimensions according to the furniture design.

It should be noted that the wooden pieces were sound without major defects (except few cracks and knots). No chemical treatment was applied and after their anatomical features the wood was identified as belonging to the spruce species (*Picea Abies* L. Karst.).

The moisture content and density were determined according to EN 322:1996 and EN 323:1996, respectively. After evaluation, all pieces were processed by: cross-cutting, straightening, planing to thickness, splitting, cut to size and grinding (Fig.2). Circular Festol KAPEX KS 120, straightening and planing machine Holzmann PT 260, milling machine Festol OF 1010 and Festool ETS 150 BQ and ROTEX 150 FEQ for grinding were used to process the raw material.

a. Cross-cut to length and defects removal

b. Straightening, planing to thickness

c. Cutting the elements to the final dimensions

d. Sanding the wooden elements with 80-120 grit sand paper

Fig.2.
Raw material came from a demolished house: a - beam; b - sawn timber from framing; c- scantling from the roof.

b. Panels resulted from fireproof test

In the building sector, the fireproofing of wood is mandatory by regulations, to reduce the risk of flames spreading in the event of a fire, among which are: technical norm C58-96 - on fireproofing of combustible materials; SR 652-2009 - checking the effectiveness of fireproofing (https://www.spatiulconstruit.ro/articol/ignifugarea-lemnului). Thus, many burnt panels resulted from fireproof tests which may be seen as possible material to be recovered. In order to be used as elements in the piece of furniture, the burnt panels were evaluated for their size, degree of combustion, and transformation possibilities (Fig.3).

Fig.3.
Panels from fireproof tests.

The panels were partially burned at one end and have the dimensions of 400mm (length), 150mm (width) and 18mm thickness. There were MDF and solid wood panels, and were used without any farther processing, by assembling two of them by epoxy resin, for extendable plates of the bedside table (Fig. 7).

c. Branches from pruning

The large number of branches and twigs after pruning are left in the forest. In this research the hazelnut branches were used to manufacture panels (Fig.4).

Fig.4.
The hazelnut branches.

Branches of similar diameter were chosen (between 5 mm to 8 mm diameter), and the density and moisture content were determined. Branches were cross-cut at the same length, and then, were horizontally layered in a wooden frame. The urea-formaldehyde adhesive was sprayed after each layer (about 500 g/board). The panel formed had 40 mm thickness and surface of 400 x 400 mm. The panel was pressed at 120^{0}C temperature during 30 minutes. The pressure was set at 80 bars for 15 minutes then was decreased to 50 bars (Fig.5).

a. **b.** **c.**

Fig.5.

The panel from branches manufacturing: a – cut to length; b – forming the panel; c – pressing.

B. Adhesives

The adhesives used for manufacturing of branches panel and reinforcement of burnt panels, were characterized in Table 1.

Table 1

Adhesives characteristics

Panel type	Adhesive type	Characteristics
1.Panel from branches	Urea-formaldehyde/ UF/ color: white and translucent shades	Solid content: 66%; density 1.273g/cm^3; pH 7.6; free formaldehyde 0.15%. Ammonium chloride was used as hardener (NH4Cl, 2% based on the resin weight).
2. Burnt panels	Transparent epoxy resin-Super Cast 10	Two-component epoxy resin, transparent and super clear. Mix in volume 100:50 (2:1). The maximum recommended thickness / layer, is 10mm. Super Cast 10 is mixed and left to harden in a room at about 20^{0}C.
3. Solid wood elements gluing	PVAc dispersion- NOVOBOND D2/ Viscous white liquid	PVAc adhesive based on polyvinyl acetate which meet the requirements of the durability class D2, suitable for indoor use.

RESULTS AND DISCUSSION

A. Manufacturing the panels and the structure of furniture

The density and moisture content of the wood waste from demolished house and from hazelnut branches are presented in Table 2.

Table 2

Density and moisture content of the raw material

Raw material	Density, kg/m^3	Moisture content, %
Wood elements from demolished house	465	12.94
Hazelnut branches	550-574	14.25-21.22

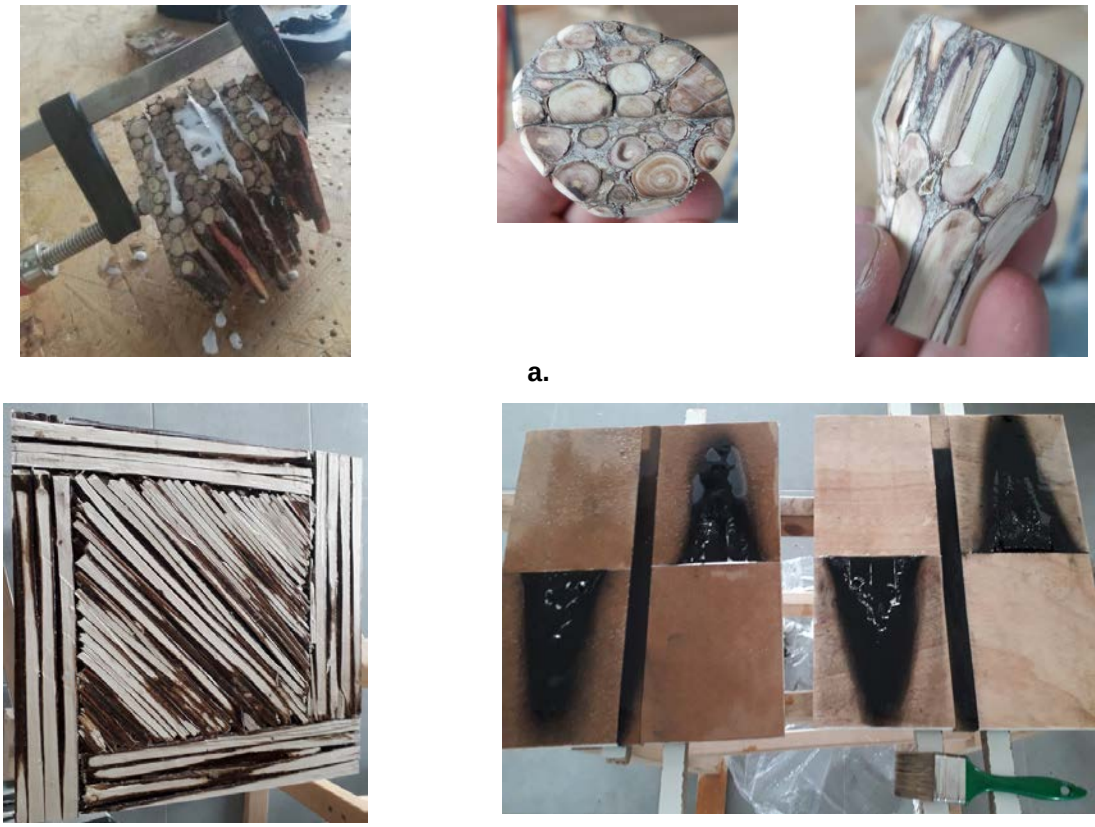
The panel from wood branches was subjected to high pressure (80 bars) to obtain a greater contact between crushed branches and adhesive. Higher moisture content of branches will generate more steam, and higher mat compression will accelerate consolidation of the panel.

The solid wood elements obtained from the wood waste of demolished house were assembled to form the rigid structure of the bedside table and the drawer, as shown in Fig.6.

The panel obtained from branches was used for the top plate and button for the drawer, and the burnt panels were reinforced with epoxy adhesive (Fig.7).

a. b. c.

Fig.6.
Assembling the elements for the piece of furniture: a – the drawer construction; b – assembling the rigid structure of bedside table; c – fitting the frame and additionally legs for extendable panels.



a.

b. c.

Fig.7.
a - The manufacture of the drawer button; b - panel from branches; c – burn panels reinforced with epoxy resin.

B. Designing the piece of furniture

A bedside table with the following dimensions has been designed: 600mm high and 400x400mm (length x width) (Fig. 8). In the extended position the upper plate has 600x1000x400mm.

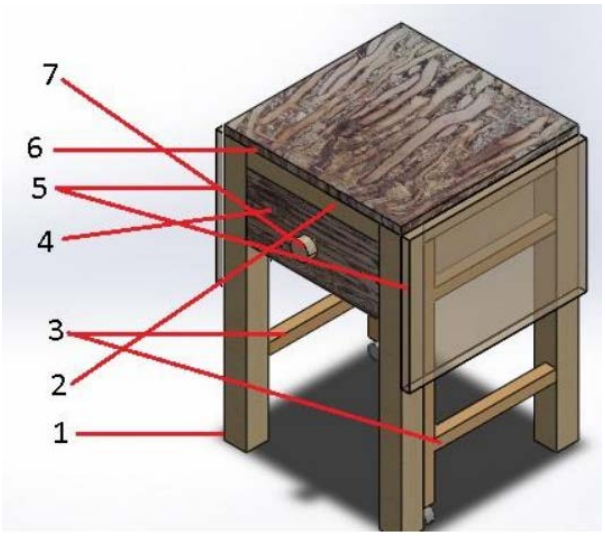


Fig.8.
Bedside table: 1-leg; 2-solid wood frame; 3-extensible support made of additionally legs; 4-drawer; 5-reinforced extendable panels from burnt wood and epoxy resin; 6- braches top panel; 7-drawer button.

The furniture is designed from the raw materials described above and included:

- a four-legged softwood frame with a section of 50x50mm; the four legs were obtained from a beam of 620x130x130mm, which was processed to the final dimensions of 600x50x50mm;
- a frame made of softwood scantling with a section of 40x25mm;
- two additionally legs with wheels to support the side tables, in the extension mode;
- a drawer made of softwood sawn timber, with dimension: 350x300x150mm;
- three top plates; one, made of branches is fixed, and the other two from burnt panels reinforced with epoxy resin, necessary for the table extension. These panels are fastened with continuous hinges and are supported by the additionally legs.

The piece of furniture was finished with ecological varnish, Kober transparent lacquer applied by brushing in two layers, at a consumption of 180g/m^2.

An original piece of furniture was created, with the surface that can be extended through the side panels and which performs multiple functions such as support items, storage things and could be also used as a coffee table.

Consumption of raw material

The raw material consumption (including wood and others materials) used to carried out the piece of furniture is showed in Table 3.

Table 3

Raw material consumption

I. **Raw wood material consumption**		
1.1.	Beam element, 620x130x130mm	**0.027972**
1.2.	Scantling, 38mm	**0.011072**
1.3.	Sawn timber, 24mm	**0.009072**
a. Total wood raw material consumption, m^3		**0.124791**
b. Burnt panels, (400x150x18mm) pieces		**4**
c. Hazelnut branches, (bulk weight), kg		**5**
II. **Wood dowels and screws**		
2.1	Dowel (Ø8x50mm), in pieces	**4**
2.2.	Screw (3.5x20mm), in pieces	**20**
2.3.	Drawer slides, pieces	**2**
2.4.	Continuous hinges	**2**
2.5.	T type hinge	**4**
2.6.	Rollers, 50mm diameter	**2**
III. **Adhesives**		
3.1.	PVAc Novobond D2, kg	**0.0123**
3.2.	Urea-formaldehyde, kg	**0.5**
3.3.	Epoxy resin Super cast 10, kg	**1.5**
IV. **Finishing materials**		
4.1	Disc sanding paper (P120, 240, 320)**,** set	**3**
4.2	P80, P100, P120, P240 **(**sheets of 230x280mm), set	**4**
4.3	Water based lacquer, in l	**1.0**

The wood raw materials (Table 3) are the representative items included in the calculation of the furniture price. Most of people assume that “custom” furniture is too expensive and generally is out of the ordinary furniture price range. The custom hand-made furniture includes much effort and time for conception, choosing the materials, thus a high labour work is necessary to create, to design a personalised piece of furniture.

CONCLUSIONS

The wood waste recovered from demolition, branches from pruning represent an alternative raw material to virgin wood. These new raw materials contribute to minimization the environmental impact and efficient use of wood materials. These were used to develop panels, highlighting their potential utilizations in ingenuous furniture elements.

Value added products were also obtained from burnt panels by reinforcement with epoxy adhesive. By creative design a piece of furniture with multiple functions was manufactured. Its unique design will fit perfectly in multiple interior spaces.

ACKNOWLEDGEMENTS

The author would like to thank Alin Olarescu Ph.D., coordinator of Festool Laboratory, from the Research and Development Institute of Transilvania University of Brasov, for the equipment provided, and to Ionel-Liviu Bodean for his contribution to this research.

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