ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 10 N° 2 2014
pp. 26-33

# WOOD - PLASTIC COMPOSITES FROM WASTE MATERIALS RESULTED IN THE FURNITURE MANUFACTURING PROCESS

***Camelia COŞEREANU***
Ass.prof.dr.eng. - TRANSILVANIA University of Brasov – Faculty of Wood Engineering
Address: B-dul Eroilor, nr. 29, 500036, Brasov, Romania
E-mail: cboieriu@unitbv.ro

***Dumitru LICA***
Prof.dr.eng. – TRANSILVANIA University in Brasov – Faculty of Wood Engineering
Address: B-dul Eroilor nr. 29, 50036 Brasov, Romania
E-mail: dumitru.lica@unitbv.ro

***Abstract:***
*The paper presents the application of waste materials resulted in the furniture manufacturing process as components for wood-plastic composites. The composites are produced from industrial byproducts, such as shavings and ABS (acrylonitrile butadiene styrene), without coupling agent. The two components are derived from industrial processes of furniture manufacturing: the first one consists of wood residues resulted from planing machine as planer shavings, and the second one from ABS edge banding operation. A wide array of mixtures varying from 100% ABS to 50% ABS: 50% shavings were used to produce eight variants of boards. Density was determined for each board and the method for the determination of ABS particle size distribution by oscillating screen method using sieve apertures up to 4mm was also applied, in order to establish the particle fractions and the distribution of their sizes. Based on ABS properties, several technologies of manufacturing wood-plastic composites from the waste materials were tested and one of them was selected. The results of the first stage analysis, when the physical integrity and the compactness of the panels' structures were tested, have shown that a maximum proportion of 30% of wood shavings is accepted in the mixture. On the other hand, the low density of the boards and their porous structure recommend further investigations for thermal and sound insulation applications.*

**Key words:** *wood-plastic; waste materials; ABS; planer shavings; particle size distribution.*

## INTRODUCTION

Acrylonitrile butadiene styrene (ABS) is a common thermoplastic with a multitude of applications in manufacturing products such as automotive components, buffer edging for furniture, musical instruments, electrical devices and protections, toys, household goods and medical equipment. As the researchers noticed, the plastic products are used nowadays more than ever before and due to the fact that they do not biodegrade for centuries and fill the landfills with their wastes, they need to be recycled (Dubey *et al*. 2010). It was proved that the performances of aged ABS resin are slightly decreased compared to the virgin ones, which proves the benefit of ABS as a recyclable material (Mantaux *et al*. 2004).

Agro-waste materials (i.e. corn stalk, reed stalk, oilseed stalk, bagasse fibers) as reinforcements for thermoplastics in the structure of wood-plastic composites are alternatives to wood fibers for obtaining sustainable products for buildings and other applications, and they have received considerable attention from industry in the last years (Nourbakh *et al*. 2010, Flandez *et al*. 2012, Ashori *et al*. 2010). The chemical composition of agro-waste fibers, in terms of lignin, cellulose and hemicelluloses contents, was found to have a strong influence on the mechanical properties of the composites (Habibi *et al*. 2008). The wood residues resulted as sawdust flour consisting of a mixture of 50% beech wood and 50% pine wood were compounded with polypropylene in order to obtain hard composite materials. It was proved that by increasing of sawdust content the Brinell hardness improved, whilst the tensile strength decreased (Kaimakci *et al*. 2014). It was also investigated the influence of the fiber type, size and content on the physical and mechanical characteristics of the wood-plastic composites (Bouafif 2009). Thus, with regard to water absorption property, the composites with bark particles resulted in lower water absorption compared to those made of wood particles.

ABS can be used between -20°C and 80°C (http://www.dynalabcorp.com/technical_info_abs.asp), having the melting point of 105°C. As seen in the literature, the researchers are concerned about the recycling of used and aged ABS, by end-of-life treating and reprocessing it into new products, a process eased by its low melting point. There is a solution to avoid filling the landfill with plastic waste, which is not biodegradable. But, there are also industrial processes where plastic residues are obtained, and this is the case of furniture manufacturing industry, where ABS waste is the result of edge banding process, where the additional material of the applied edge is removed by a leveling milling operation. This plastic waste is presented in the form of fibers and generally it is extracted together with wood dust, bringing the disadvantage of sorting it. There are also solutions to extract ABS waste in individual bags, so to not affect the quality of wood waste, which can thus be transformed in wood briquettes and pellets (Fig.1).

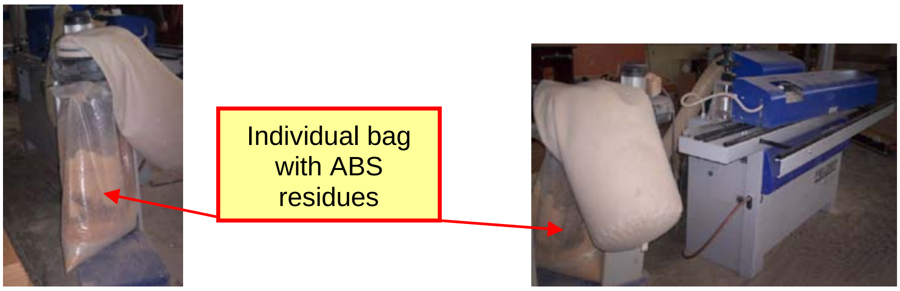


***Fig. 1.***
***ABS edge banding machine and the waste resulted after leveling milling operation.***

Because the actual trend is to manufacture ecological and green materials using biomass, waste and recycled materials, the research presented in this paper intend to use ABS waste together with planer shavings (a mixture of beech and spruce wood) to design and manufacture wood-plastic composite boards. First of all, the distribution of size particles was determined by oscillating screen method using sieve apertures up to 4mm and after that, the technology was established several mixtures ranging from a ratio of 100% ABS: 0% shavings to 50% ABS: 50% shavings were used to make eight types of boards. Afterwards it was analyzed the physical integrity of the boards when handling them, in order to select the ones with potential use and to determine their densities. Further research results for the determination of the other physical characteristics, except density (swelling in thickness and water adsorption, thermal conductivity and sound adsorption) will show the possible applications of these new wood-plastic composites.

**OBJECTIVES**

The main objective of this study is to present a solution of recycling the waste materials resulted in the furniture manufacturing sector, and for this purpose two types of materials were selected: a thermoplastic material used for edge banding the particleboard panels (ABS = acrylonitrile butadiene styrene) and wood waste in form of planer shavings (beech wood and spruce wood), from which eight boards were manufactured with mixtures ranging from a ratio of 100% ABS: 0% shavings to 50% ABS: 50% shavings. In order to establish the right technology of manufacturing the panels, the distribution of ABS size particles was analyzed by oscillating screen method, using sieves apertures up to 4mm. A first visual analysis of the physical integrity and compactness of the manufactured panels was done afterwards, in order to make a selection of the panels with potential use, and to establish thus, the appropriate ratio of ABS: shavings. As a first stage, the paper presents the results of ABS particle size distribution, the technology of obtaining the wood-composite panels from a mixture of ABS waste and planer shavings and the densities of the panels. Further research will focus on the determination of the other fundamental physical characteristics (swelling in thickness and water adsorption, coefficient of thermal conductivity and sound adsorption coefficient) in order to make recommendations of the possible applications of these wood-plastic composites.

**METHOD, MATERIALS AND EQUIPMENT**

In the present research the waste materials used as raw material for making wood-plastic composites are presented in Fig. 2. ABS waste which results in the process of particleboard edge banding consist of small soft particles of various colors. Wood shavings resulted in the wood production process on the planning machine are a mixture of beech wood and spruce wood residues.


***Fig. 2.***
***Waste materials resulted in the furniture manufacturing process.***

ONLINE ISSN 2069-7430
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PRO LIGNO
www.proligno.ro
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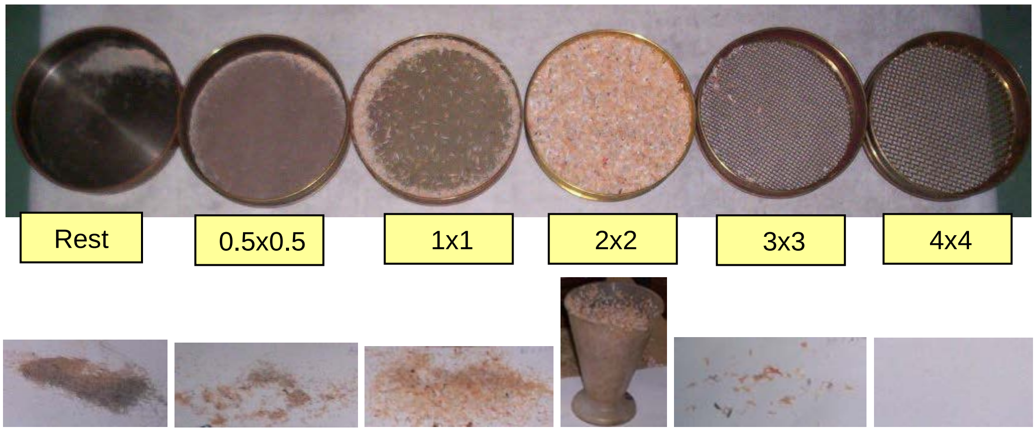
Eight wood-plastic composite panels were manufactured from the above mentioned raw materials. The proportion of the components is shown in Table 1.

*Table 1*

***Proportion of the components ABS waste - wood shavings, in %***

| Panel no. | Proportion of components, in % | | | |
|---|---|---|---|---|
| | ABS | | Wood shavings | |
| 1. |  | 100 |  | 0 |
| 2. | | 90 | | 10 |
| 3. | | 85 | | 15 |
| 4. | | 80 | | 20 |
| 5. | | 70 | | 30 |
| 6. | | 65 | | 35 |
| 7. | | 55 | | 45 |
| 8. | | 50 | | 50 |

Particle size distribution is that characteristic which is expressed by the participation rate of particles with the same sizes into the sample. ABS waste particles were investigated as sizes and fractions of participation. The sample was established to have a mass of 25g. The sample was sieved succesively starting with the larger meshes and ending with the fine ones (4x4, 3x3, 2x2,1x1 and 0.5x0.5mm) by oscillating screen method. The apparatus (Fig. 3.) was adjusted to a maximum frequency amplitude in order to obtain optimum fractions of particles. After 10 minutes the particles were collected from each sieve and weighted with an accuracy of 0,01g.




**a** **b**

***Fig. 3.***
***Oscillating screen method using sieve apertures up to 4mm for the determination of particle size distribution: a – apparatus; b – fractions of the sample collected in the sieves.***

The distribution of particle sizes is defined by the ratio (Eq. 1) and the sieve type (Fig. 3):

$$Cd = (m_f / m_p) \cdot 100, [\%] \quad (1)$$

where $m_f$ is the mass of the reed particles retained in the sieve, in g;
$m_p$ – the mass of the sample, in g.

A quarter of each fraction collected in the sieve was selected and measured, so to determine the size of particles in each fraction, according to quartering method (Lunguleasa *et al*. 2009).

The rate of particle length distribution is calculated according to equation 2:

$$P_l = (n/ N) . 100, [\%] \quad (2)$$

where n is the number of particles within the length range;
N - the total number of particles.

The particles distribution on width groups depends on the number of particles and it is calculated with equation 3.

$$P_{w} = (n/N) \cdot 100, \ [\%] \qquad (3)$$

where n is the number of particles having the width included in the specific width range;
N - total number of particles measured.

The particles' lengths and widths were measured after scaning the selected particles of each fraction and transfering them in AutoCAD .dwg file, where they were measured at scale 1:1, as seen in Fig. 4. Several examples from each fraction are shown in Fig. 4.

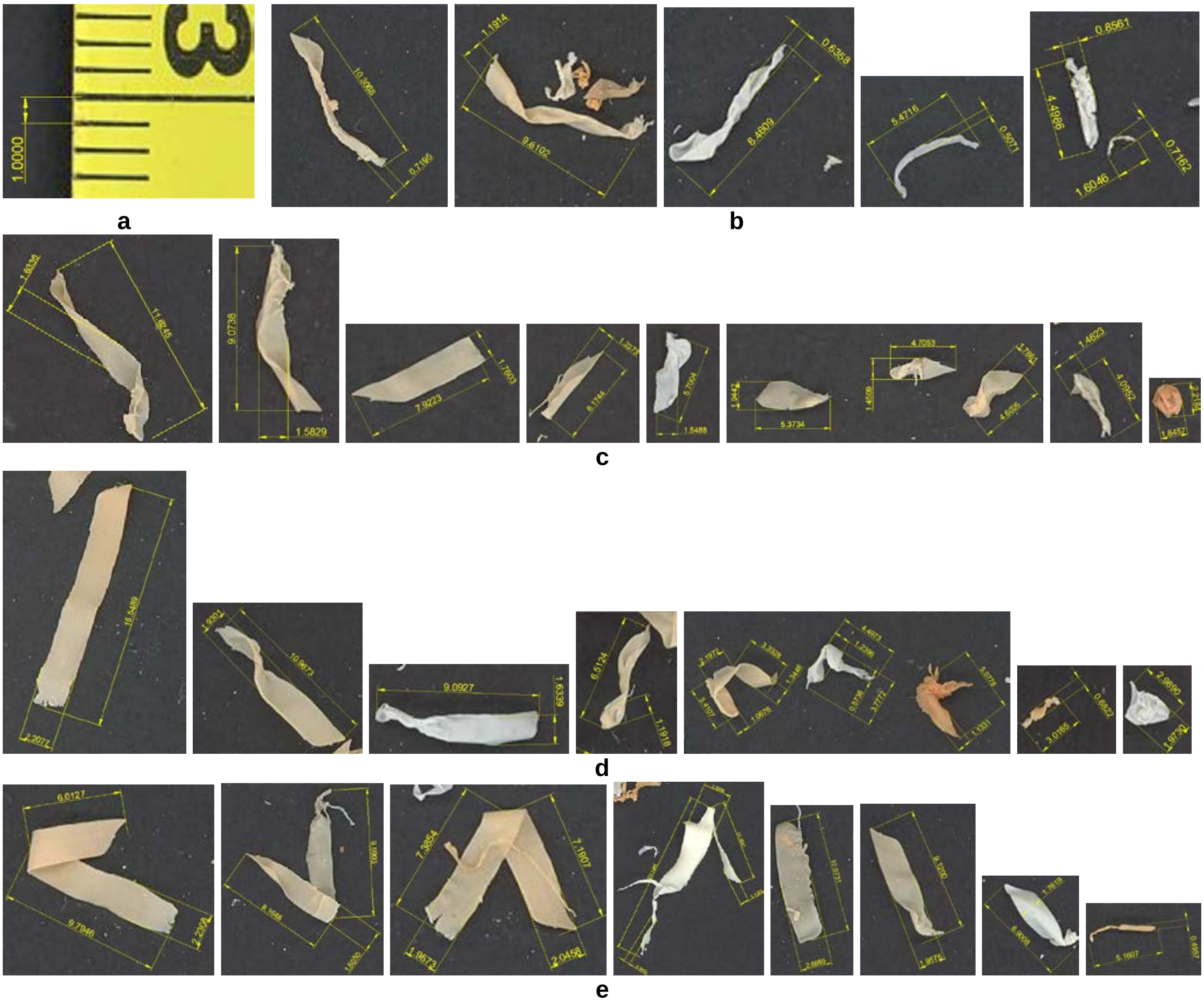



***Fig. 4.***
***Measurements of particles' lengths and widths in AutoCAD software, in mm:***
***a – measurement calibration; b – fraction 0.5x0.5mm; c – fraction 1x1mm; d – fraction 2x2mm;***
***e – fraction 3x3mm.***

The eight wood-plastic composite panels made of ABS waste and wood shavings in the proportions shown in Table 1 are presented in Fig. 5. The components were mixed mechanically and introduced in special chipboard frames with the dimensions of 620x620x18mm. A thermo-resistant foil (PTFE) was provided for the top cover and lower cover of the frame, and parchment paper for the sides, in order to form the edges of the panels. The technology of obtaining the wood-plastic composites from ABS waste and wood shavings is presented in Table 2. This technology was established after several attempts where parameters as temperature, pressure and pressing time were changed increasingly. The starting temperature point was 105°C, the melting point of ABS resin (http://www.dynalabcorp.com/technical_info_abs.as).

For lower temperatures, lower pressure and a shorter pressing time the compactness of the panels was poor. Instead, for higher values of the parameters, the appearance of the panel surface was not homogeneous, portions of waved surface were present on both faces and changes of initial colors were noticed because of burned areas.


***Fig. 5.***
***The eight wood-plastic composite panels made of ABS waste and wood shavings.***

*Table 2*

***Technology of obtaining wood-plastic composites from ABS waste and wood shavings***

| Panel no. | Operation/ Phase | Parameters/ Picture |
|---|---|---|
| 1. | Preparing the frame, PTFE foil and parchment paper. |   |
| 2. | Mixing the two components |  |
| 3. | Pouring the components into the frame |  |
| 4. | Leveling the upper surface of the mixture |  |
| 5. | Covering the frame and mixture with parchment paper |  |
| 6. | Putting the upper cover and introducing in the press | Temperature: 130°C<br>Presure: 20bar<br>Pressing time: 20min |

ONLINE ISSN 2069-7430
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PRO LIGNO
www.proligno.ro
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## RESULTS AND DISCUSSIONS

The fractions resulted in the sieves of 0.5x0.5mm, 1x1mm, 2x2mm, 3x3mm, 4x4mm, as percent of the sample of 25g are presented in Fig. 6. As noticed, the more numerous particles were retained by sieve 2x2mm (82%) and the fewest particles were retained by sieve 3x3mm. No particles were retained by sieve 4x4mm.

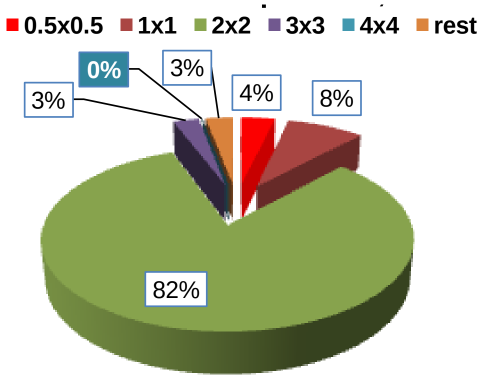


***Fig. 6.***
***Fractions of ABS particles (Cd), in %.***

In order to measure the length and the width of the particles, a quarter of each fraction corresponding to each sieve type was selected, and the number of particles was counted. The results of particle distribution for lengths range ($P_l$) and for width range ($P_w$) are shown in Table 3.

*Table 3*

***Distribution of particle sizes in length range ($P_l$) and in width range ($P_w$), in %***

| Length/ Width | | Distribution of particle sizes (%) in length range ($P_l$) and in width range ($P_w$), for all fractions (in mm) collected in the sieves | | | | | Weighted average % |
|---|---|---|---|---|---|---|---|
| | | 4x4 | 3x3 | 2x2 | 1x1 | 0.5x0.5 | |
| Lengths range, in mm | L>15 | - | 12.3 | 6.6 | 0.0 | 0.0 | **5.0** |
| | L=10.1-15 | - | 43.2 | 10.0 | 6.3 | 5.8 | **13.0** |
| | L=5-10 | - | 19.8 | 55.0 | 41.7 | 33.1 | **44.0** |
| | L<5 | - | 24.7 | 28.4 | 52.1 | 61.2 | **38.0** |
| Widths range, in mm | <0.5 | - | 13.6 | 3.1 | 10.4 | 8.3 | **6.6** |
| | 0.5-1.00 | - | 9.9 | 7.8 | 16.7 | 77.7 | **23.1** |
| | 1.01-2.00 | - | 27.0 | 20.1 | 72.9 | 14.0 | **28.0** |
| | 2.01-2.50 | - | 22.2 | 69.0 | 0.0 | 0.0 | **38.6** |
| | >2.5 | - | 27.3 | 0.0 | 0.0 | 0.0 | **3.6** |

As seen from the analysis of particle fractions and sizes, the particles of ABS waste are small sized ones, just 5% having the length exceeding 15mm, the more numerous particles having lengths in the range 5-10mm (44%). The higher percentage of the particles having the widths in the range 2-2.5mm is explained also by the more numerous fractions collected in the sieve 2x2mm. The particle fractions and sizes have influence upon the technological parameters of manufacturing the wood-plastic composite panels made of ABS waste, and the results of this analysis is directly connected to the values of temperature, pressure and pressing time of the provided technology in the experiment. Changes of the fractions and particle sizes could have influence upon the technological parameters.

The densities of the obtained panels are shown in Fig. 7. The panels studied in the present paper have low density values, ranging between 218 and 243kg/m$^3$. As noticed, the density of the panel increases with the increasing of wood shavings participation. The diagram in Fig. 7 shows a polynomial dependence between the wood shavings percentage and the density of the panels.

The final analysis of the manufactured panels was done for checking their physical integrity and compactness when manipulating them. Only the first five ones behaved accordingly, so they were selected for the next experimental determinations: 2hours and 24hours immersion into the water for the determination of water adsorption and thickness swelling, thermal insulating properties expressed by the thermal conductivity coefficient and sound adsorption coefficient. After this first stage of the experimental research presented in the paper the results show that the participation of wood shavings together with ABS waste in wood-plastic composites is maximum 30%.

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ISSN-L 1841-4737
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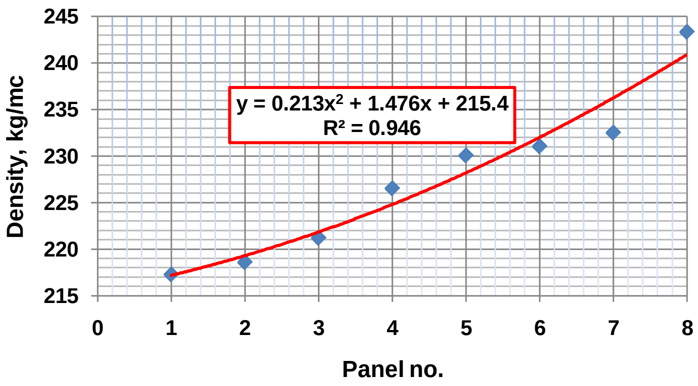


***Fig. 7.***
***Densities of the wood-plastic composite panels made of ABS waste and wood shavings.***

The defects occurred at panels 6, 7 and 8 at their manipulation are shown in Fig. 8. They present fragile structures, weak edges and easy to break corners.


***Fig. 8.***
***Defects occurred at manipulation: a – panel 6; b – panel 7; c – panel 8.***

**CONCLUSIONS**

The present research offers a solution of recycling waste materials resulted in the furniture production process and we refer to ABS waste material resulted from edge banding machine and wood shavings resulted from planing machines (planer shavings). From the eight variants of mixtures ABS: wood shavings, only the first five variants proved to have the potential use. These variants of panels had up to 30% wood shavings in their mixture. The rest ones have presented fragile structures, breaks on the edges and corners when manipulating them.

The panels presented in this study proved to have low densities and a porous structure, fact that indicate possible applications of these panels, and we refer to thermal and sound insulation applications.

The study regarding the particles fractions and sizes distribution of ABS waste particles have shown that this waste material is composed of small sized particles with a majority of particles of maximum 10mm length and 0.5 – 2.5mm width. For these particle sizes, the appropriate technological parameters used to manufacture the wood-plastic composite panels proved to be as follows: temperature: 130°C, pressing time: 20min. and pressure: 20bar.

The selected panels for potential applications (panels 1, 2, 3, 4 and 5) need further experimental determinations of thickness swelling and water absorption after 2h and 24 hours of immersion in water and also the determination of thermal conductivity coefficient and sound adsorption coefficient.

A first stage of analyzing the proposed panels indicates that a possible application for them could be in thermal or/and sound insulation field. The further testing results will show if it is true and they will indicate the appropriate structures for this type of applications.

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