FLEXURAL TESTS IN CASE OF SOME COMPOSITES REINFORCED WITH CARPINUS/BEECH WOOD FLOUR

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Abstract: The paper describes the aspects concerning the manufacturing process and mechanical characteristics of some wood flour/carabamide resin composite materials. In this paper, the specimens were manufactured by reinforcing a carabamide resin Urelit R (urea-formaldehyde resin) with beech wood flour or carpinus wood flour. The hand lay-up technology was used to prepare the specimens. Then, the composite specimens were subjected to the flexural test (three point method). Finally, a comparison concerning the results obtained in cases of the two kinds of filler used, shows that the mechanical properties of the carpinus wood flour/urea-formaldehyde resin composite material are a little better than the ones corresponding to the composite material filled with beech wood flour. Finally, taking into account the values of mechanical characteristics, the low costs of manufacture of the involved composite and the necessity of the recycling of the wood waste resulted from more fields of the industry; the paper notes some recommendations for practical applications of these composite materials.

Key words: composite material; carpinus wood flour; beech wood flour; flexural test.

1. INTRODUCTION

Nowadays, it is known the great interest for recycling of the large amount of wood waste (Kandem et al., 2004) obtained during the different stages in the wood processing and wood applications such as furniture industry and building constructions. On the other hand, there were preoccupations concerning the recycling of the fibre materials (Bartl et al, 2005) such as the textiles, carpets, composite materials reinforced with fibres etc.

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Some previous studies (Kandem et al., 2004) had already shown that the wood wastes in the form of wood flour, fibres or pulp is suitable as a filler for polyolefin matrix composites or for recycled plastics. Moreover, the using of the straws together with wood flour as filler (Simonsen, 1996), was a proven solution to manufacture new composite material.

Some researchers (Adhikary et al., 2008) shown that the composites made of high-density polyethylene and pinus wood flour as filler, treated with coupling agents (polypropylene maleate, 3–5 wt %), could be desirable as building materials due to their improved stability and strength properties.

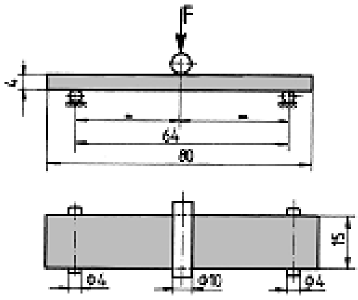
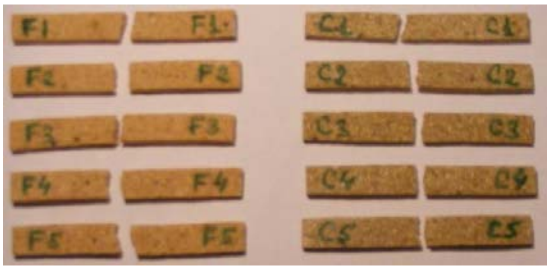


Fig. 1. Dimensions of the specimen and scheme of loading for the bending test



a) b)

Fig. 2. Specimens made of urea-formaldehyde resin reinforced with:
a) Beech wood flour; b) Carpinus wood flour.

Although the use of wood filler in plastic composites has several advantages over inorganic fillers, it may be safely said that the hydrophilic nature of the wood has a negative effect on performances of the wood-plastic composites. This assumption is based on some previous researches (Cerbu, 2007) on the degradation of the mechanical characteristics of the composite materials made of E-glass/urea-formaldehyde resin Urelit R, due to the moisture absorption.

Worldwide, there is a lot species of wood depending of the location on globe due to the nature of the climate. For example, for the temperate zone, among the specific species of wood could be: fir; oak; beech; carpinus specie; poplar; willow; maple, chestnut; wood of the fruit trees such as bird cherry, walnut and so forth. This means that practically, there are more kinds of wood flour or wood fibre that may be used as filler for a composite material based on polymer resins or urea-formaldehyde resins.

This paper focus on the mechanical properties of wood flour/resin composite materials, which were made by using the urea-formaldehyde resin Urelit R with carpinus/beech wood flour as filler. The composite panels were made by using the hand-layup technology. Certainly, the technology and the structural composition directly affect the mechanical properties of the composite material resulted (Cerbu et al., 2008). To mechanically characterize the composite materials the flexural test (three point method) was used.

2. MATERIALS AND METHODS

The first of all, the composite plates having the dimensions 350 × 250 mm^2 are manufactured. It may note that one of the composite plates was made of carpinus wood flour/urea-formaldehyde resin *Urelit R* while the other one plate was reinforced with beech wood flour. The wood flour content was 150 g in case of both plates to reinforce 700 ml urea-formaldehyde resin Urelit R.

Some characteristics of the urea-formaldehyde resin Urelit R (carabamide resin) used without reinforcing are shown in the table 1. *Urelit ® R* is a urea-formaldehyde resin with higher stickiness and cold setting. The product is made by *S.C. Viromet S.A.* and it is usually used in the wood processing industry for bordering PAL panels, for pasting solid elements and for the manufacture of doors and windows.

Table 1. **Characteristics of the urea-formaldehyde resin Urelit R without reinforcing**

Characteristic name	Limits	Unit of measure	Testing Methods
Appearance	weakly opalescent, viscous liquid	-	Visual
Density at 20 °C	1.33 ± 0.03	g/cm^3	STAS 35-81
Dynamic viscosity at 20 °C	1000 - 3000	mPa s	STAS 117-87
Solid substance, 2 h at 120 °C	70 ± 2	%	SR 6643-96
pH	7.5 ± 0.5	-	SR 6643-96
Free formaldehyde, max.	3.50	%	SR 6643-96
Shearing stress of pasting in dried state, min	8	MPa	SR 6643-96
Gelatinization time at 20°C, max.	45	minutes	SR 6643-96

Before flexural test, the specimens were kept at room temperature and dried environment for three weeks. Moreover, the specimens were additionally dried by using an air oven at 35 °C during two days.

Then, the specimens where cut from each plate for the bending test (three-point method). The dimensions of the specimen and the scheme of loading (three-point method) for the flexural test are shown in the figure 1 according to the actual european standards (SR EN ISO 178, 2001).

The testing equipment used for flexural test consists of a hydraulic power supply. The maximum force capacity is ±15 kN. During the flexural tests, the speed of loading was 1.5 mm/min like the european standard (SR EN ISO 178, 2001) recommends. The figure 2 shows a photo of the specimens after the flexural tests.

The experimental results recorded in the flexural test for the carpinus wood flour/urea-formaldehyde resin composite were compared with the ones obtained in case of the beech wood flour/urea-formaldehyde resin composite.

Before each flexural test of a specimen, the dimensions of the cross-section were accurately measured (table 2) and then, they were considered as input data in the software program of the machine. The testing equipment allowed us to record pairs of values (force F and deflection v at midpoint of the specimens, stress σ and strain ε) in form of files having 200-300 lines. The testing machine gave us the results of a statistical calculus for each set of specimens tested. Therefore, the average values of the following quantities could be automatically computed: Young's modulus E in bending; flexural rigidity EI_z; maximum bending stress σ_{max} at maximum load; deflection v_{max} at maximum load; maximum bending strain ε_{max} at maximum load; mechanical work to maximum load etc.

Table 2. **Some geometrical characteristics of the specimens tested**

	Carpinus wood flour/urea-formaldehyde resin composite					**Beech wood flour/urea-formaldehyde resin composite**				
Specimen No.	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Width, mm	9.4	9.4	9.6	9.7	9.7	9.9	9.8	9.5	9.7	9.9
Thickness, mm	3.9	4.4	4.6	4.3	4,1	4.8	4.6	4.8	4.3	4.8
Axial moment of inertia I_z, mm^4	46.467	66.727	77.869	64.268	55.711	91.238	79.491	87.552	64.268	91.238
Strength modulus W_z, mm^3	23.829	30.331	33.856	29.892	27.176	38.016	34.561	36.480	29.892	38.016

3. RESULTS AND DISCUSSIONS

Experimental results recorded during bending tests in case of all specimens tested, may be graphically drawn by using F-v coordinates (Fig. 3 and Fig. 4). It may observe that F-v curves obtained in case of the carpinus wood flour/urea-formaldehyde resin composite (Fig. 3), are located a little above the curves recorded for the composite specimens made of beech wood flour/urea-formaldehyde resin (Fig. 4).

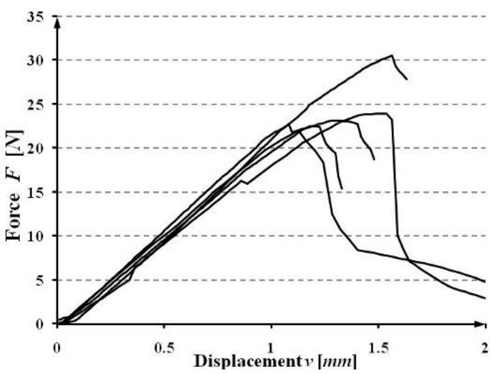


Fig. 3. F-v curves recorded for the carpinus wood flour/urea-formaldehyde resin

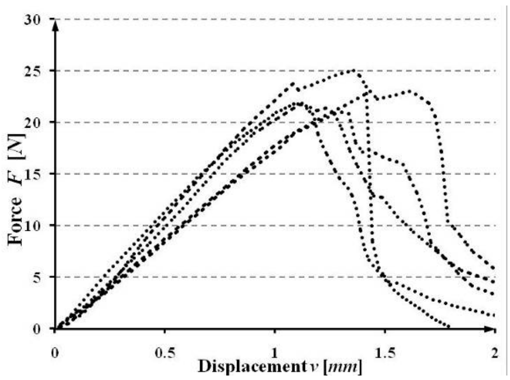


Fig. 4. F-v curves recorded for the beech wood flour/urea-formaldehyde resin

It follows that the stiffness of the composite material filled with carpinus wood flour is greater than the stiffness of the ones filled with beech wood flour.

The experimental results concerning some mechanical characteristics (flexural modulus *E*, flexural stress σ_{max} at maximum load, mechanical work done at maximum load) for the all specimens tested are shown in the figures 5-7, respectively.

It may be noted that Young's modulus was computed on the linear portion of the σ-ε curve. It may remark that generally speaking, the both Young's modulus *E* for bending and maximum normal stress σ_{max} have lower values in case of the composite material filled with beech wood flour than in case of the composite filled with carpinus wood flour (Fig. 5 and Fig. 6).

The mean values of the mechanical characteristics graphically plotted (figures 5-7) and other experimental results may be found in the table 3.

It may observe (Fig. 5) that in case of the carpinus wood flour/urea-formaldehyde resin composite, the Young's modulus *E* is equal to 919.5 MPa, approximately with 37.5 % greater than the value *E* = 668.5 MPa obtained in case of the composite material filled with beech flour. On the other hand, the flexural stress σ_{max} = 10.5 MPa at maximum load (Fig. 6), obtained in case of the carpinus wood flour/urea-formaldehyde resin composite is with approximately 32.9 % greater than the value σ_{max} = 7.9 MPa recorded for the other one composite material tested.

Table 3. **Mean values of some mechanical characteristics obtained by flexural test**

Type of the composite material	**Unit of measure**	**Carpinus wood flour/urea-formaldehyde resin Urelit R**	**Beech wood flour/urea-formaldehyde resin Urelit R**
Young's modulus *E*	MPa	919.5	668.5
Flexural stress σ_{max}	MPa	10.5	7.9
Mechanical work done until maximum load	N·mm	17.7	15.8
Flexural rigidity EI_z	$\times 10^4$ N·mm²	6.7128	6.2387
Maximum load F_{max}	N	24.445	22.904
Extension at maximum load v_{max}	mm	1.3656	1.4059
Maximum bending strain σ_{max} at maximum extension		0.014025	0.015686

Analysing the experimental results shown above (figures 5-7, table 3), the most important remark is generally speaking that the mechanical characteristics (Young's modulus *E* and maximum normal stress σ_{max}) of the composite material filled with carpinus wood flour, are a little better than the same characteristics recorded in case of the composite material filled with beech wood flour. Therefore, the specimens made of composite material filled with carpinus wood flour are a little stiffener than the ones made of composite filled with beech wood flour.

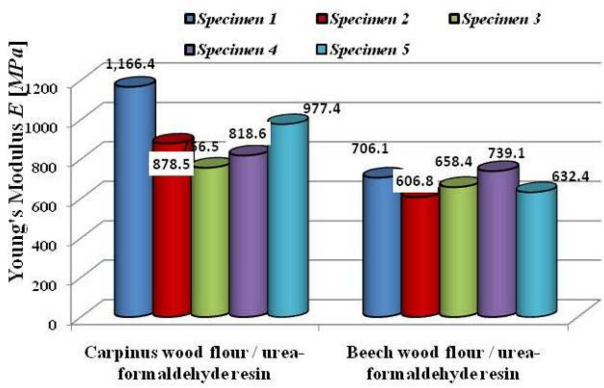


Fig. 5. Experimental results concerning Young's modulus *E* in case of the flexural tests

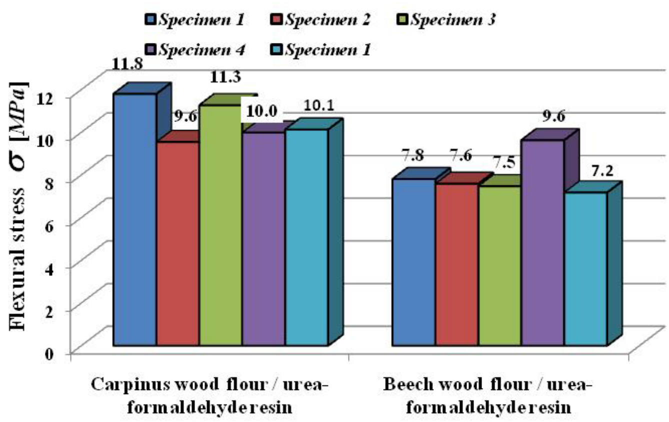


Fig. 6. Experimental results concerning the flexural stress σ_{max}

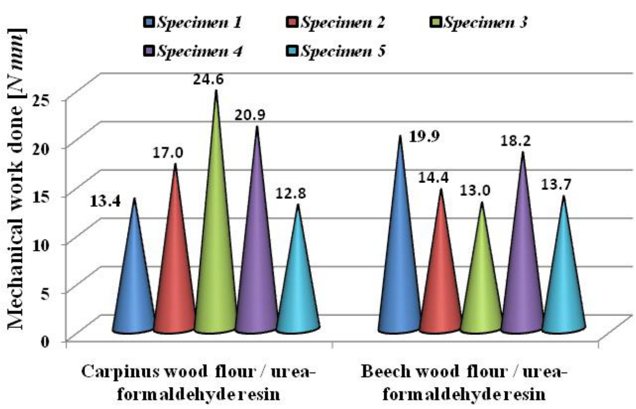


Fig. 7. Experimental results concerning the mechanical work done until maximum load

In case of the composite material made of carpinus wood flour/urea-formaldehyde resin Urelit R, since the value of the flexural rigidity EI_z is greater than the one obtained in case of the composite material filled with beech wood flour, the both extension v_{max} at maximum load and maximum bending strain ε_{max} at maximum load are a little lower. The experimental results shown in the table 3, concerning the maximum extension at maximum load v_{max} show that the specimens made of beech wood flour/urea-formaldehyde resin Urelit R (v_{max} = 1.4059 mm) are a little flexible (about with 2.95 %) than the specimens made of composite material filled with carpinus wood flour (v_{max} = 1.3656 mm). However, the mechanical work done until maximum load (table 3) is a little greater in case of the composite material filled with carpinus wood flour. The reason could be the better strength of that composite.

4. CONCLUSIONS

Like the others researches, analysing of the actual experimental results shows that the manufacture of the composite materials with urea-formaldehyde resin filled with carpinus/beech wood flour could be one of the good solutions recommended for the recycling of the wood wastes resulted from the wood industry.

Taking into account the low mechanical characteristics in bending, these kinds of composite materials filled with carpinus/beech wood flour, should be used only to manufacture products that are not strength members in furniture industry or building constructions. However, taking into account the recycling necessity of the large quantity of wood wastes, the low costs of manufacture for the new composites, it may recommend them for the boards in construction, furnish ornaments, carcasses, electrical switches, plating, coatings etc.

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