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Modeling the properties of bio-composites obtained from plastic and wood waste for building applications

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Abstract – **In this study, bio-composite material obtained from recycled polyethylene (RPE) blended with wood flour (WF) used as fillers in presence of different percentage of compatibilizer agent as maleic anhydride (MA) was studied in an attempt to modeling the properties of composite for building applications as wood plastic composites (WPCs).**

Keywords – municipal solid wastes, wood plastic composites, mechanical analysis, dielectric analysis

I. INTRODUCTION

In the last years, due to the increasing cost of raw materials and the continuous reduction of natural resources, the recycling has become an interesting option for reducing the impact of industrialization upon the environment [1]. The benefits of recycling are by diverting waste away from landfills and by providing raw materials for new products. Several waste materials, like, e.g., recycled plastics, glass, cellulose, tire cords, and wood and carpet fibres, exhibit extreme versatility, light weight, durability, resistance to chemicals, excellent thermal and electrical insulation properties. Such properties can be usefully exploited to build-up innovative and sustainable composite materials [2]. New trends in the construction sector require building materials to be used efficiently and respect the environment throughout the life of a building *[3].*

However, recycled thermoplastic polymers lack sufficient strength and stiffness for use in some engineering applications. Plastics reinforced with organic or inorganic fibres, can be used in a wide range of applications in construction, due to the benefits they provide over the traditional building materials. Wood plastic composites (WPCs) can be considered as sustainable materials, as the wood can be obtained from landfill agro waste material, and the plastics can be mainly derived from consumer and industrial recycling efforts, as municipal solid wastes [4]. Main advantages of these composite materials include lightweight structure, excellent resistance to corrosion and rot, and also good fire behaviour that means less maintenance and repair, and low costs of a life cycle [3]. WPCs are easier and facilitate better handling during the assembly process, reducing installation costs and transport costs, also provide a greater freedom of design that allows creation of complex shapes and can be processed like wood, so can be nailed, fastened with screws, can be cut with conventional tools and can easily be painted.

The manufactured process of WPCs from RPE included 3 steps: (1) the flakes resulting from cutting PE waste are granulated with extruder, (2) PE granules, wood flour and compatibilizer agent are mixes in extruder and produces the wood–plastic granules; (3) the moulding process. The injection, compression, and extrusion are the typical moulding processes of which the wood–plastic granules form the desired shapes [5].

The properties of WPCs are affected by many parameters, i.e. wood species, the compounding and moulding temperature/pressure [6]; the uniformity distribution of components [7], and the formula of the compositions [8]. The size of wood particles and source of recycled resins should affect the performance of WPCs therefore the coupling agents are added in WPCs to improve the bonding between wood flour and the polymer matrix. [9].

In this study, bio-composite material obtained from recycled polyethylene (RPE) blended with wood flour (WF) used as fillers in presence of different compatibilizer agent as maleic anhydride (MA) was studied in an attempt to modeling the properties of composite for building applications [10].

II. MATERIALS AND METHODS

As the matrix component, were prepared recycled polyethylene (RPE) derived from recycling plastic containers. Wood flour from polishing the furniture was used as filling material. Three types of compatibilizers C 0.3, C 0.5, C 0.7 with a different percentage of maleic anhydride 0.3, 0.5 and C 0.7 respectively.

Before blending, both natural polymers and compatibilizers were subjected to an oven conditioning treatment for 24 hours at a temperature of 105 °C and 50 °C, respectively. Then, the mixture was introduced into a single screw extruder having a diameter of 19 mm, a length/diameter ratio 25. During the extrusion, the temperature profiles of the four processing zones were 130–140–140–145 °C. The extruded material was transformed into granules of 3-6 mm size by means of a granulator and then the composite granules were processed into 1 x 235 x 235 mm plates (thickness x width x length) by flapping and then hot pressing at a pressure of 150 bar at temperature of 150 °C for 10 minutes. From these plates were cut off dumbbells (1.35 x 10 x 90 mm), which were characterized by mechanical properties, water absorption and dielectric characteristics, Fig. 1. Before analysing the samples, these were conditioned by maintaining then into a vacuum oven for three hours to 50°C and 0.98 kPa pressures. Composite materials were obtained according to the method presented, and the compositions of experimental specimens are presented in Table 1.

Mechanical dielectric and and water absorption proprieties of WPCs were investigated. The mechanical tests were performed with a testing machine Tiratest 2200 according to STAS 6642-73. The impact strength has been evaluated using a testing machine Izod Pendulum 540/228062 according to STAS 7310-87. The dielectric tests were carried out with dielectric analyzer Novocontrol Concept C 80 system, running in a frequency range from 10^{-2} up to 10^{6} Hz.

Fig. 1. Specimens of WPC for test

Table 1. Material compositions of tested wood–plastic composites.

Specimens	*Matrix*	*Compatibilizer agent*			*Filling material*
	RPE	*C 0.3*	*C 0.5*	*C 0.7*	*WF, %*
RPE/WF	*80*	*-*	*-*	*-*	*20*
RPE/WF/C 0.3	*77*	*3*	*-*	*-*	*20*
RPE/WF/C 0.5	*77*	*-*	*3*	*-*	*20*
RPE/WF/C 0.7	*77*	*-*	*-*	*3*	*20*

III. RESULTS AND DISCUSSIONS

The results of the mechanical tests reveal that, by introducing the compatibilizers into blends, all the mechanical properties improve compared to the mixtures without compatibilizing. In the case of maximum load at break test, the results of the materials containing compatibilizers increase by ~50%, the highest value being recorded for the composite containing the C 0.5 compatibilizer 149.56 N/mm^2, Fig. 2. Also, strength at break diagram show that the type of compatibilizer is not influence the results of WPCs, Fig.3.

In the case of maximum elongation results show that the percentage of maleic anhydride presents in compatibilizers influences the WPCs behavior, Fig. 4. The diagram of elongation at break confirms that C 0.3 have optimal amount of maleic anhydride to obtain positive results, Fig.5.

The Young's modulus diagram, Fig.6 present composites containing compatibilizers whose results increases substantially due to better link of wood flour and the polymer matrix provided by the interaction of the maleic anhydride from additive with the OH functional groups of the polymer and the wood.

In the case of hardness Shore D with the increase in the maleic anhydride content in the compatibilizer, the values of this property decrease, Fig.7. The impact strength show a better result only for composites with compatibilizer agent C 0.3 which contain a minimum amount of anhydride, Fig. 8.

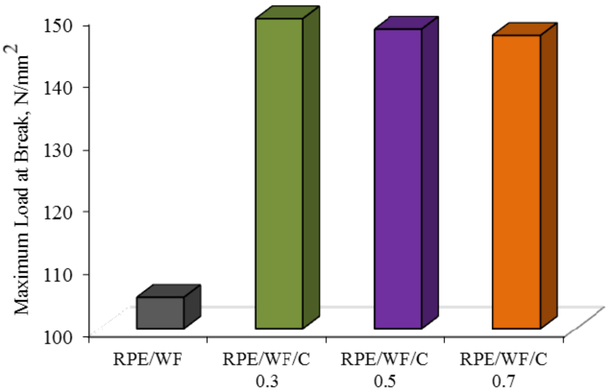

Fig. 2. Maximum load at break results for WPCs

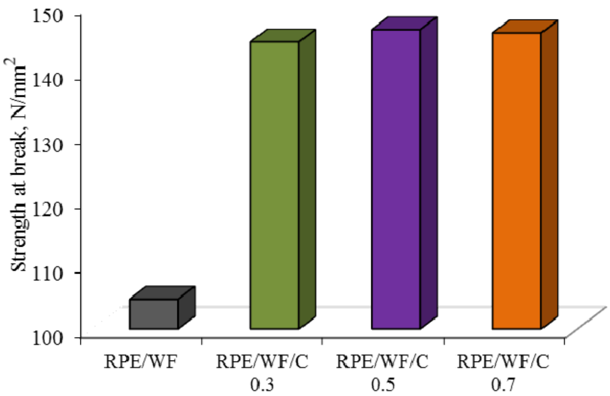

Fig. 3. Strength at break results for WPCs

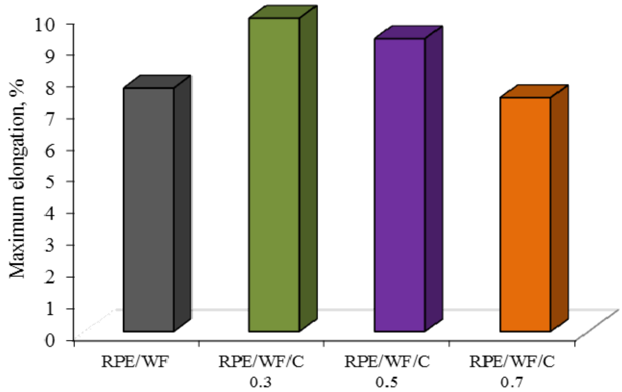

Fig. 4. Maximum elongation results for WPCs

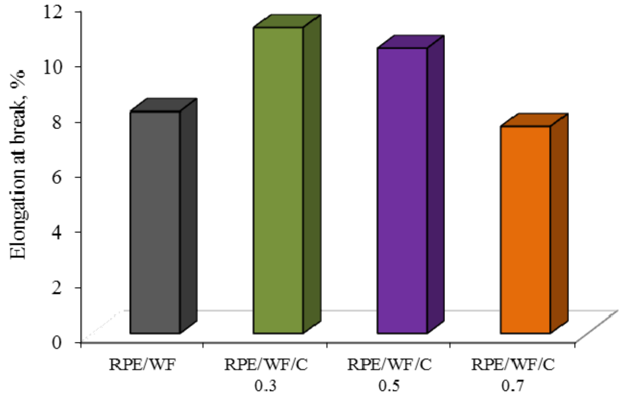

Fig. 5. Elongation at break results for WPCs

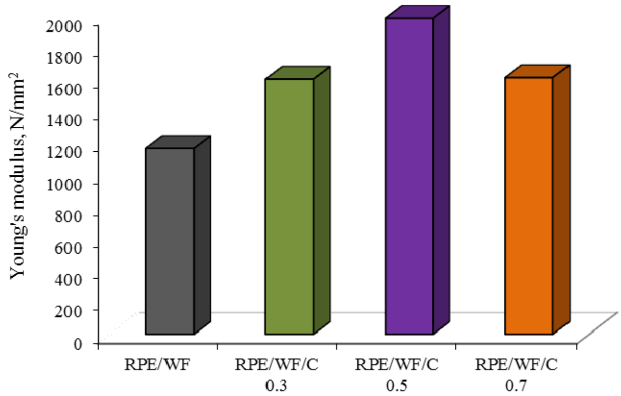

Fig. 6. Young's modulus results for WPCs

The mechanical results indicate a proper behavior for composite with C 0.3 compatibilizer agent.

The mechanical results values was correlated and discussed in relation to the dielectric characteristics of RPE. The dielectric constant ε' and tan δ of WPCs is illustrated graphically in Fig. 9 and Fig. 10 function of frequency.

Dielectric properties show a significant change only in up to 100 Hz, after this value of frequency the electric dipoles are unable to track rapid variations of the electric field applied by the dielectric spectrometer. The dielectric constant diagram shows the influenced of the compatibilizer agent; however no correlation can be made between quantity of agent and dielectric results value.

The dielectric constant curve of composite with C 0.7 compatibilizer agent has the slightest value while curve of composite with C 0.5 is recorded with highest values. The composite with C 0.7 compatibilizer agent has the highs value for tan δ compared to the rest of the composites. From dielectric characterization, it seems that, composite material with C 0.3 compatibilizer agent provided superior dielectric behavior, Table 2.

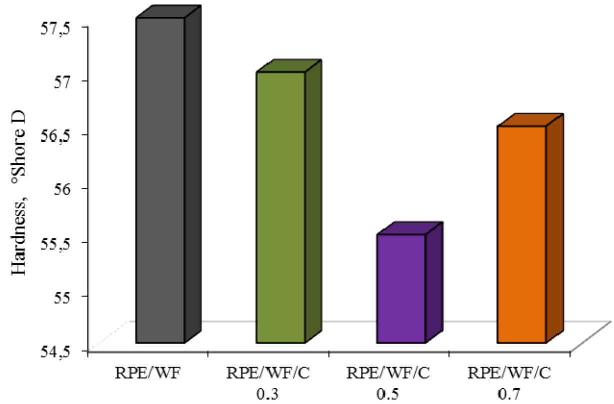

Fig. 7. Hardness, Shore D for WPCs

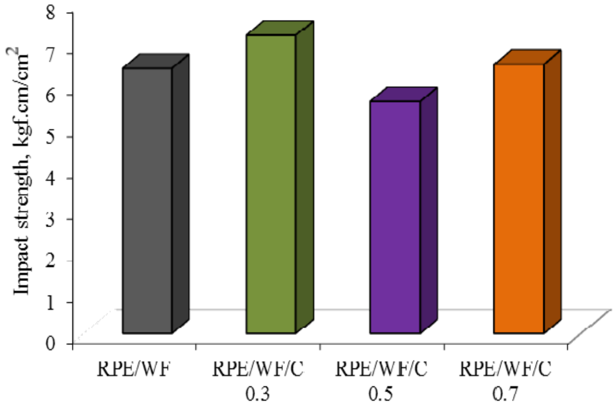

Fig. 8. Impact strength for WPCs

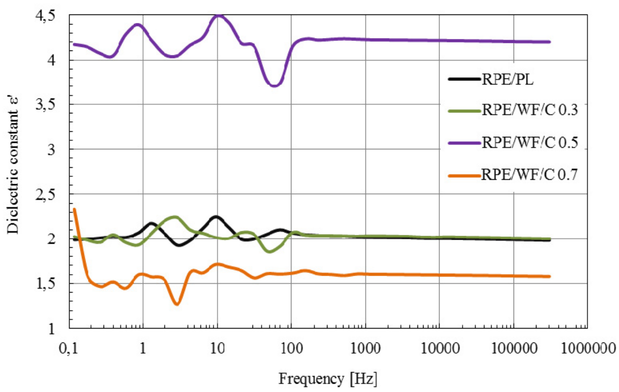

Fig. 9. Dielectric constant result for WPCs

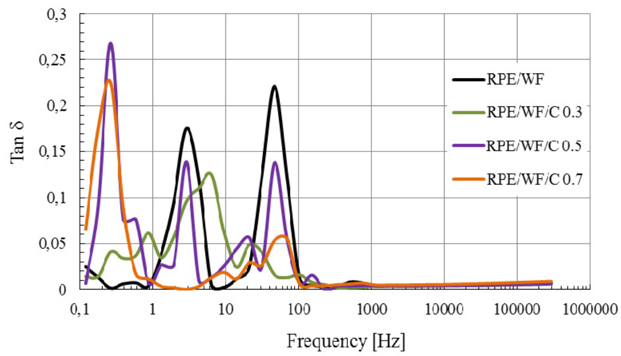

Fig. 10. Tan δ result for WPCs

Table 2. Dielectric properties of RPE /WF mixtures with various compatibilizers.

Dielectric proprieties	Freq. [Hz]	RPE/ WF	RPE/ WF/ C 0.3	RPE/ WF/ C 0.5	RPE/ WF/ C 0.7
Conductivity σ, [S×cm]	60 100 1000	1,52.10^{-12} 4,33.10^{-13} 4,98.10^{-12}	2,14.10^{-12} 6,54.10^{-13} 4,90.10^{-12}	3,11.10^{-13} 1,34.10^{-12} 8,57.10^{-12}	3,31.10^{-12} 6,49.10^{-13} 4,04.10^{-12}
Resistivity ρ_v, [Ω×cm]	60 100 1000	6,56.10^{11} 2,30.10^{12} 2,00.10^{11}	4,66.10^{11} 1,52.10^{12} 2,03.10^{11}	3,21.10^{12} 7,42.10^{11} 1,16.10^{11}	3,02.10^{11} 1,54.10^{12} 2,47.10^{11}
Impedance Z_p, [Ω]	60 100 1000	5,22.10^{9} 1,83.10^{10} 1,59.10^{8}	3,71.10^{9} 1,21.10^{10} 1,62.10^{9}	2,55.10^{10} 5,90.10^{9} 9,27.10^{8}	2,40.10^{9} 1,22.10^{10} 1,97.10^{9}
Capacity C_p, [F]	60 100 1000	2,33.10^{-11} 2,26.10^{-11} 2,24.10^{-11}	2,33.10^{-11} 2,27.10^{-11} 2,26.10^{-11}	2,99.10^{-11} 3,09.10^{-11} 3,06.10^{-11}	1,78.10^{-11} 1,79.10^{-11} 1,78.10^{-11}
Modulus	60 100 1000	4765,7 4911,2 4957,1	4750,3 4891,1 4915,2	3708,0 3600,7 3628,2	6213,6 6187,9 6235,3

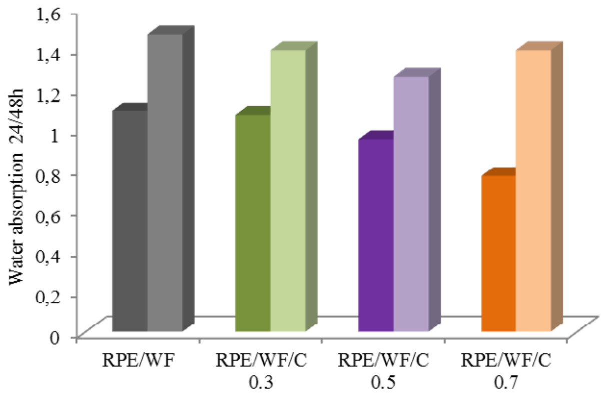

Fig. 21. Water absorption results at 24 and 48h of WPCs

The compatibilizers agents used do not increase the water absorption capacity of the composite materials but on the contrary, compared to materials with no compatibilizers agents, they reduce the amount of water absorbed.

It is noted that the higher the amount of maleic anhydride grafted onto the copolymer, the lower the amount of water retained. The immersion time of the samples in water causes the percentage of water absorbed to increase.

IV. CONCLUSIONS

This study investigated the effects of different compatibilizer agent which changing material compositions to the mechanical and dielectric properties of extruded WPCs composed of RPE) blended with wood flour (WF) used as fillers. The optimal compositions in mass content for the studied materials were composite with 20% wood flour and C 0.3 compatibilizer agent. This combination confirmed some changing effects regarding reference values of the composition in an attempt to modeling the properties of composite for building applications.

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