Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 82, 2013: 287-290
(Ann. WULS - SGGW, For. and Wood Technol. 82, 2013)

Effect of soaking on mechanical properties of wood-polymer composite with impregnated wood particles

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Abstract: *Effect of soaking on mechanical properties of wood-polymer composite with impregnated wood particles.* The main purpose of this study was to determine the effect of soaking wood plastic composites containing impregnated coarse wood particles on the mechanical properties (flexural modulus, flexural strength) of these composites. The composites were made from softwood particles used for manufacturing three-layer particleboard and polyethylene. Wood particles were impregnated with two kinds of impregnates. The samples were prepared by injection moulding in a ratio of 40/60% - wood/polymer. It was found out that soaking these WPCs in water for two weeks does not significantly affect the flexural strength, but it causes a slight reduction of the flexural modulus.
Filling polyethylene with wood protected by impregnate reduces thickness swelling.

Keywords: wood-plastic composite (WPC), mechanical properties, impregnation, recycling

INTRODUCTION

Modern wood industry is first of all governed by the principles of the rational economy of materials. Thus, solid wood is more and more frequently, where possible, being replaced with alternative materials such as for example wood plastic composites (WPCs). WPC is a compound of a polymer matrix and lignocellulosic particles. Apart form standard polymer fillers such as wood flour, wood particles and wood fibres (Bledzki and Faruk 2003, Cui et al. 2008) other lignocellulosic particles are also used like sawdust and wood sanding flour (Gozdecki et al. 2007a), rice husk fibres, rice straw leaf fibres, rice straw stem fibres (Yao et al. 2008). For ecological reasons it is particularly important to use wood wastes as a filler of WPCs. A significant part of wood wastes are elements derived from demolition of buildings, garden architecture, poles or railway sleepers. They contain most of the chemical preservatives such as impregnates, flame retardants and other ones (McLaren and Smith 1996, Ashori et al 2012). Generally, an addition of chemical preservatives has a marginal effect on mechanical properties (Ayrilmis et al. 2012, Behzad et. Al. 2012) but it affects increases in the fire and biological resistance of WPC.

A very wide range of the usage of WPC causes that such a composite is also frequently used in products that come into direct contact with water, e.g. platforms and terraces. However, WPC has a lower water absorption in comparison to products made of solid wood. It is very important to examine in what degree impregnating a wood filler affects the mechanical properties of water-soaked WPCs.

Therefore, the aim of the study was to determine an effect of soaking WPCs containing impregnated wood particles (WPs) on the mechanical properties of these WPCs.

MATERIALS AND METHODS

Polyethylene HDPE Tipelin 550-13 produced by Basell Orlen Poliolefins (density 956 kg/m^3) was used as a matrix. Industrial soft WPs used for manufacturing three-layer particleboards were employed as raw wood material. were screened by an analytical sieve shaker LAB-11-200/UP using the sieves of 35 and 5 meshes to obtain particle sizes: 0.5-4 mm. WPs smaller than 0.5 and larger than 4mm were removed. After screening the wood materials were dried in a laboratory oven at 102^o C to achieve a moisture content of 0-2%. One third of dried WPs were treated with an oil-wax based (OW) preservative called Protector W-2 obtained from Dekspol PPH Poland. The second group of WPs were treated with a solvent based (S) preservative Atlax produced by Atlax Sp.z o.o. Poland. The third group was not impregnated (control group – C). Wood particles were mixed with a polymer in a ratio of 40/60% - wood/polymer. Test specimens were made by injection moulding using a screw injection moulding machine Wh-80 Ap.

To assess the effect of soaking on the mechanical properties of WPCs, the composites were divided into two groups: WPCs not soaked and WPCs soaked in water for 14 days. Water absorption and thickness swelling were determined after 14 days. The flexural modulus and strength were determined according to EN ISO 178. Cross-head speed was 2 mm/min. Ten replicates were run for each test. All tests were performed at a room temperature (21^{o}C) and constant relative humidity (50%)

RESULTS

Results of the ANOVA test on the effect of soaking on the WPC mechanical properties are presented in Table 1.

Tab. 1 ANOVA test on the effect of soaking on WPC mechanical properties (*p*- value)

Flexural modulus			**Flexural strength**		
Kind of composite					
WPC/C	WPC/S	WPC/OW	WPC/C	WPC/S	WPC/OW
<0.001	0.006	<0.001	0.1605^{ns}	0.4951^{ns}	0.3276^{ns}

ns - not significant at $\alpha = 0{,}05$

The results of investigations into the effect of soaking WPCs containing impregnated WPs on mechanical properties are presented in Fig. 1. Error bars represent one standard deviation based on ten specimens. The physical properties (water absorption and thickness swelling) of tested composites are shown in Fig.2. The significance of the difference between mean values of a given property was evaluated by Tukey's HSD test. The same letters, indicates that there is no significant difference (at $\alpha = 0{,}05$) for a given property between compared composites.

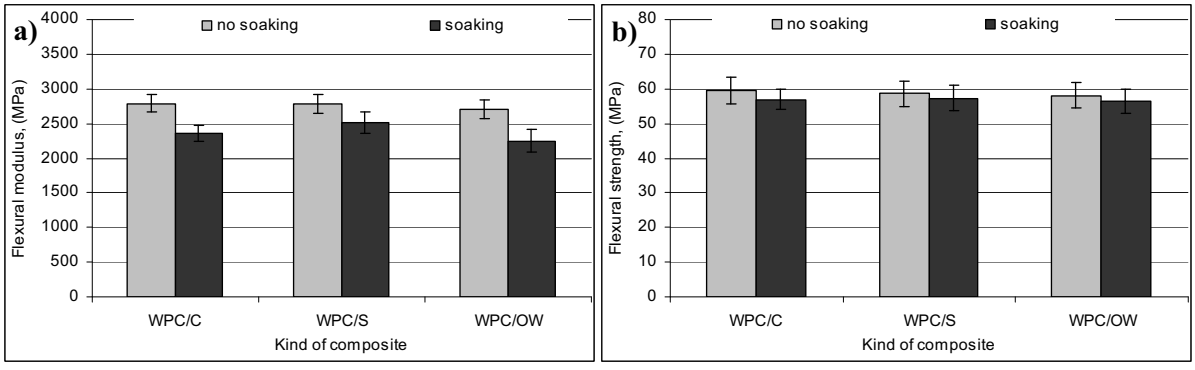

Fig. 1 Mechanical properties of tested composites: a) flexural modulus, b) flexural strength.

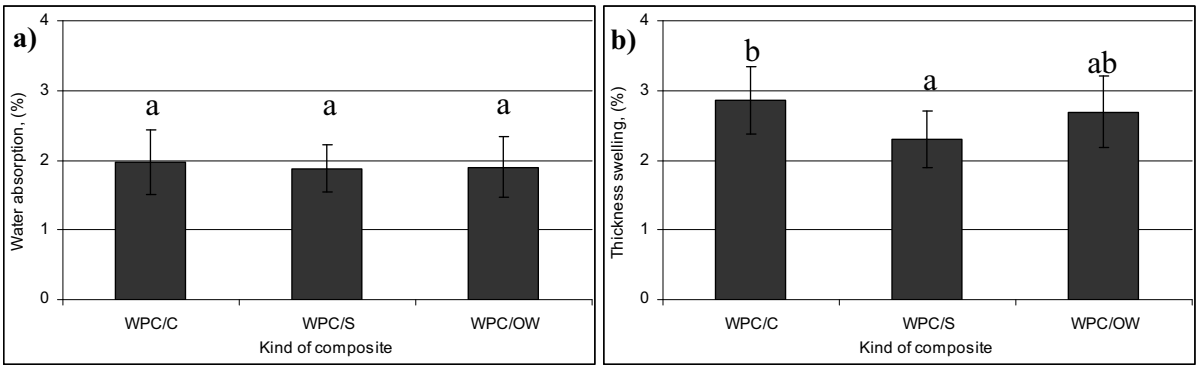

Fig. 2 Physical properties of tested composites: a) water absorption, b) thickness swelling.

The results of statistical analysis (Table 1) show that soaking WPCs did not significantly affect the flexural strength of WPCs regardless of whether a wood filler was impregnated or not. It is unlike in the case of flexural modulus. Soaking composites containing impregnate and composites without impregnate for 2 weeks affected this mechanical property in a statistically significant way. The flexural modulus of water-soaked WPC/C was lower on average by 15% than that of WPC/C not soaked in water. In the case of WPC/S and WPC/OW flexural modulus was lower on average by 9% and 17% than that of these composites which were not soaked, respectively (Figure 1).

Soaking composites in water for two weeks results in an increase in their water absorption and thickness swelling. Filling polyethylene with wood protected by S or OW reduces thickness swelling on average by 19% and on average by 6% as compared to WPC/C, respectively. No statistically significant differences were noted between the values of water absorption of the WPC/C and WPC/OW or WPC/S (Figure 2).

CONCLUSIONS

The research results allow to conclude that WPs treated by S and OW impregnates can be efficiently used for fabrication of WPCs based on HDPE. It was found out that soaking these WPCs in water for two weeks does not significantly affect the flexural strength but it causes a slight reduction of the flexural modulus.

Filling polyethylene with wood protected by S or OW reduces thickness swelling and does not significantly affect water absorption as compared to WPC/C.

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Streszczenie: *Wpływ moczenia na właściwości mechaniczne kompozytu drzewno-polimerowego zawierającego impregnowane cząstki drzewne.* Głównym celem badania było określenie wpływu moczenia kompozytów polimerowo-drzewnych zawierających impregnowane duże cząstki drzewne na właściwości mechaniczne (moduł sprężystości, wytrzymałość na zginanie) kompozytów. Kompozyty zostały wykonane z wiórów iglastych stosowanych do wytwarzania trzywarstwowej płyty wiórowej i polietylenu. Cząstki drzewne nasycano dwoma rodzajami impregnatów. Próbki przygotowano metodą wtryskiwania do formy w stosunku 40/60% - drewno/polimer. Stwierdzono, że impregnacja drewna w niewielkim stopniu zmniejsza moduł sprężystości WPC oraz nie wpływa istotnie na ich wytrzymałość na zginanie. Napełnianie polietylenu impregnowanymi cząstkami drewna zmniejsza pęcznienie WPC.

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