Original scientific paper
Received:21.6.2019
Accepted:5.12.2019
UDK: 674-419:539.4

SCREW WITHDRAWAL RESISTANCE OF COMPOSITE WOOD-BASED PANELS (PART II)

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ABSTRACT

The aim of the research presented in this paper is to determine screw withdrawal resistance of composite wood-based panels intended for use in construction.

For this purpose, three experimental wood composite panels were made by combining particleboards and constructive peeled veneers of beech, black pine and poplar with thickness of 1,5 and 3,2 mm. The core layer of the composite panels was made of single-layer particleboard with thickness of 16 mm, which was overlaid on both sides with two-ply cross-laminated veneers. Models of composite panels were made by combining a different veneer species for particleboard overlay (beech/black pine, poplar/black pine and poplar/beech).

Water-soluble phenol-formaldehyde resin was used for particle bonding and veneering.

The results of the research showed that different combinations of veneer species used for particleboard overlay significantly impact screw withdrawal resistance of composite panels.
According to the obtained values of screw withdrawal resistance, composite panels can be used in construction.

Key words: composite wood-based panels, particleboard, veneer, beech, black pine, poplar, phenol formaldehyde resin, screw withdrawal resistance

1. INTRODUCTION

Composite wood-based panel represents a composition of particleboard and veneers (particleboard core overlaid with peeled veneers) which combine structural efficiency with favorable manufacturing cost (Biblis and Chiu, 1974). These kinds of panels are intended for structural use in construction.
Properties of composite panels made from various core and face materials have been investigated by many authors (Hse, 1976; Biblis and Mangalousis, 1983; Biblis 1985; Chow *et al.*, 1986; Dimeski *et al.*, 1996 and 1997; Miljković *et al.*, 1997; Mihajolva *et al.*, 2005; Iliev *et al.*, 1994, 2000, 2005, 2006, 2010; Buyuksari, 2012; Jakimovska Popovska *et al.*, 2015, Jakimovska Popovska *et al.*, 2017, Jakimovska Popovska and Iliev, 2017).

Researches that concern the dimensional stability of the panels under water impact were conducted by Iliev, 2006; Jakimovska Popovska *et al.*, 2014; Mihajolva *et al.*, 2005. Possibilities for improving water resistance properties of composite panels were investigated by Hse *et al.* (2012). Iliev (2000) and Norvydas and Minelga (2006) studied the impact of the number of the veneers on composite panels' properties.

Beside other physical and mechanical properties of composite wood-based panels that are important for structural use in construction, screw withdrawal resistance is also an important property that can show the behavior of the assemblies of this kind of wood-based panels made with screws. Strength and stability of structures made from particleboards depend very much on the fastening that holds the parts of the structure together (Miljković and Popović, 2004).

The withdrawal resistance of composite panels made from single-layered particleboard overlaid with single veneers and cross-ply laminated veneers was studied by Jakimovska Popovska *et al.*, 2016 and Jakimovska Popovska and Iliev, 2017. Studies about screw holding performance of wood-based materials were carried out by many authors (Eckelman, 1975 and 1988; Miljković *et al.*, 2007; Erdil *et al.*, 2002; Điporović-Momčilović *et al.*, 2006); these studies can be used to develop estimates of face and edge screw holding strength that can be used in product engineering of constructions made from wood-based materials.

2. MATERIALS AND METHODS OF THE EXPERIMENTAL WORK

Three experimental composite wood-based panels were made by combining single-layered particleboard and peeled beech, black pine and poplar veneers. The core layer of composite panels was a single-layer particleboard with thickness of 16 mm which was overlaid on both sides with two-ply cross-laminated veneers from beech, black pine and poplar with thickness of 1,5 and 3,2 mm, where the veneers with thickness of 1,5 mm represent the surface layers of the panels (Fig. 1). All three composite models have a different combination of veneer species for particleboard overlay.

Mix of equal weight ratios of particles for core and surface layer was used for manufacture of the single-layered particleboards, where water solution of phenol-formaldehyde resin was used as an adhesive for particle bonding with 16 % dry matters content on dry wood basis. The characteristics of the resin and pressing parameters used for manufacture of the single-layer particleboards are described in a previous paper (Jakimovska Popovska and Iliev, 2017).

The particleboards were overlaid with two veneer sheets on each side of the panels. Combinations of beech, black pine and poplar veneers with thickness of 1,5 and 3,2 mm were used for overlay. The orientation of the adjacent veneers was at right angle, where the surface veneers with thickness of 1,5 mm were oriented parallel to the longitudinal axis of the particleboard. A water-soluble phenol-formaldehyde resin with 48,85% dry matters content was used for veneer bonding. Wheat flour was used as filler and 15 % water solution of $Ca(OH)_2$ as catalyst. The binder was applied on both sides of the inner veneers with thickness of 3,2 mm in quantity of 180 g/m^2.

The veneering was made in a hot press using specific pressure of 15 kg/cm^2, pressing temperature of 155°C and pressing time of 20 minutes. The composite panels were overlaid with phenol-formaldehyde resin impregnated paper during the hot pressing process.

The produced panels have moisture content of 8,5 % and dimensions of 545×435 mm^2, with thickness ranging from 23,02 to 23,34 mm depending on the model.

According to this methodology three models of composite wood-based panels were made:

– model B-BP: water-resistant composite panel made of particleboard core overlaid with two-ply cross-laminated beech and black pine peeled veneers (black pine surface layers);
– model P-BP: water-resistant composite panel made of particleboard core overlaid with two-ply cross-laminated poplar and black pine peeled veneers (black pine surface layers);
– model P-B: water-resistant composite panel made of particleboard core overlaid with two-ply cross-laminated poplar and beech peeled veneers (beech surface layers).

The configuration of the structure of the composite panels is shown on figure 1.

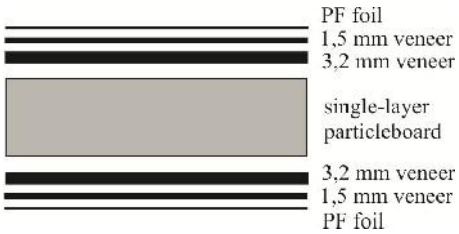

Figure 1. *Pattern of the structure of composite panels*

Screw withdrawal resistance of composite panels was tested according to MKS D.C8.112/82. This property was tested in two directions: perpendicular to the plane of the panel, i.e., when the screw was driven in the surface of the panel and in plain of the panel (the screw was driven in panel's edge).

Nine test specimens of each model were made with dimensions of 100×50×d mm. Slotted flat countersunk head wood screws according to standard DIN 97 were used for these tests. The technical parameters of the screws and dimensions of the screw holes pre-drilled in the panels are given in a previously published paper (Jakimovska Popovska and Iliev, 2017).

The tests were performed on a universal testing machine, measuring the maximal force of withdrawal.

The specific screw withdrawal resistance perpendicular to the plane of the panel was calculated using the following equation:

$$Z_{\perp}=\frac{F}{d\times\pi\times(d_1-2}\ [\mathrm{N/mm^2}],$$

where F is maximal force of screw withdrawal [N], d is the diameter of the screw [mm] and d_1 is the thickness of the panel.

The specific screw withdrawal resistance parallel to the plane of the panel was calculated using the following equation:

$$Z_{\parallel}=\frac{F}{d\times\pi\times l}\ [\mathrm{N/mm^2}],$$

where F is maximal force of screw withdrawal [N]; d is the diameter of the screws [mm] and l is the depth of driving of the screw into the panel's edge.

The obtained data was statistically analyzed. One way ANOVA was used to determinate the significance of the effect of veneer overlay on panel's screw withdrawal resistance perpendicular to the plane of the panel. Tukey's test was applied to evaluate the statistical significance between mean values of the property of composite panels with different veneer overlay (different panel models). Statistical software SPSS Statistic was used for statistical analysis of the obtained data.

3. RESULTS AND DISCUSSION

The values of the density of composite models are shown in table 1.

Table 1. *Statistical data for density of the composite panels*

Model	***N***	***Mean***	***Min***	***Max***	***95% Confidence Interval for Mean***		***Std. Deviation***	***Std. Error***
		kg/m³	***kg/m³***	***kg/m³***	***Lower Bound***	***Upper Bound***	***kg/m³***	***kg/m³***
B-BP	9	721,22[a]	697,00	773,00	704,36	738,09	21,94	7,31
P-BP	9	681,89[b]	651,00	714,00	662,33	701,45	25,44	8,48
P-B	9	719,33[a]	644,00	756,00	690,50	748,16	37,51	12,50

The mean values with the same letters are not significantly different at 0,05 probability level

The highest density of composite models is achieved in model B-BP, i.e. in the model overlaid with beech and black pine veneers. The ANOVA (F(2,24)=5,24; p=0,013) and Tukey's test for density of the composite panels showed that the model made with poplar and black pine veneers (P-BP) statistically differs from the other two models. Different combinations of veneers for particleboard overlay will produce panels with different density depending on the wood species used for veneer production.

Analysis of variances of the data obtained for screw withdrawal resistance perpendicular to the plain of the panel (ANOVA: F (2; 24)=4,107; p=0,029) showed that the differences between the mean values for this property in at least two models are statistically significant, which means that the

combination of different wood species used for particleboard overlay has significant impact on this property. The conducted post-hoc Tukey's test for multiple comparison between models showed that there are statistically significant differences in the mean value of this property between models P-BP and P-B. The differences in the mean values of screw withdrawal resistance perpendicular to the plain of the panel between model B-BP and model P-BP, as well as between models B-BP and P-B are not statistically significant.

The highest mean value of this property is achieved in composite model that is overlaid with beech and poplar veneers, while the lowest value is achieved in model made with black pine and poplar veneers.

Analysis of variances of the data obtained for screw withdrawal resistance parallel to the plain of the panel (ANOVA: F (2; 24)=17,317; p=0,000) and post-hoc Tukey's test for multiple comparison between models showed that there are statistically significant differences between the mean values of this property in all composite models. These differences can be a result of an inadequate mixture of particles for production of single-layered particleboards that is obtained with mixing of equal weight ratios of particles for core and surface layer. Further investigations are needed to confirm this statement. The edge withdrawal resistance also depends on the quality of the bonds between particles (Miljković, 1991).

Table 2. *Statistical data for screw withdrawal resistance perpendicular to the plain of the composite panels*

Model	N	Mean	Min	Max	95% Confidence Interval for Mean		Std, Deviation	Std, Error
		N/mm²	N/mm²	N/mm²	Lower Bound	Upper Bound	N/mm²	N/mm²
B-BP	9	12,81[a,b,c]	11,27	14,99	11,96	13,66	1,10	0,37
P-BP	9	11,31[b]	9,89	13,19	10,42	12,19	1,15	0,38
P-B	9	13,24[c]	8,71	15,33	11,66	14,81	2,05	0,68

The mean values with the same letters are not significantly different at 0,05 probability level

Table 3. *Statistical data for screw withdrawal resistance parallel to the plain of the composite panels*

Model	N	Mean	Min	Max	95% Confidence Interval for Mean		Std, Deviation	Std, Error
		N/mm²	N/mm²	N/mm²	Lower Bound	Upper Bound	N/mm²	N/mm²
B-BP	9	2,04[a]	1,75	2,37	1,89	2,18	0,19	0,06
P-BP	9	2,65[b]	1,89	3,43	2,25	3,06	0,53	0,18
P-B	9	3,24[c]	2,50	4,18	2,86	3,63	0,50	0,17

The mean values with different letters are significantly different at 0,05 probability level

The obtained values of screw withdrawal resistance of the experimental composite panels are within the limits of the values listed in the literature concerning similar researches. Jakimovska Popovska and Iliev (2017) give the values in the limits of 11,92 to 14,11 N/mm^2 for screw withdrawal resistance perpendicular to the plain and from 2,65 to 3,00 N/mm^2 for screw withdrawal resistance parallel to the plain of the composite panels made with two-ply cross-laminated veneers. Iliev (2000) gives the values in the limits of 9,95 to 11,90 N/mm^2 for screw withdrawal resistance perpendicular to the plain and from 5,42 to 7,92 N/mm^2 for screw withdrawal resistance parallel to the plain of the composite panels made with single beech veneer overlay. The same author gives the values within the limits of 9,69 to 12,95 N/mm^2 for screw withdrawal resistance perpendicular to the plain of composite panels made of two-ply cross-laminated beech veneers and values within the limits of 4,19 to 7,21 N/mm^2 for screw withdrawal resistance parallel to the plain of the panel. Miljković *et al.* (1997) give the value of 12,13 N/mm^2 for composite panel made with two-ply cross-laminated black pine veneers. Jakimovska Popovska *et al.* (2017) give the values in the limits of 11,12 to 13,00 N/mm^2 for screw

withdrawal resistance perpendicular to the plain of the composite panels with single veneer overlay and values in the limits of 2,61 to 2,71 N/mm^2 for screw withdrawal resistance parallel to the plain of the composite panels.

4. CONCLUSIONS

Based on the results obtained from the research conducted, one can conclude that the combinations of veneers from different wood species used for particleboard overlay in production of composite panels has significant impact on the values of screw withdrawal resistance perpendicular to the plain of the composite wood-based panels. The highest mean value of this property is achieved in composite model made with beech and poplar veneer overlay.
By combining water resistant particleboard as core layer and peeled constructive veneers for particleboard overlay, composite wood-based panels for structural application in construction can be made.

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