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NAIL WITHDRAWAL RESISTANCE OF COMPOSITE WOOD-BASED PANELS MADE FROM PARTICLEBOARD CORE AND PEELED VENEERS FROM DIFFERENT WOOD SPECIES

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ABSTRACT

This paper elaborates the nail withdrawal resistance of composite water-resistant wood-based panels for use in construction.

Three experimental 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 composite panels was made from single-layer particleboard with thickness of 16 mm. Particleboards were overlaid on both sides with two-ply cross-laminated veneers.

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

The results of the research showed that the different combination of veneer species used for particleboard overlay significantly impacts the nail withdrawal resistance perpendicular to the plain of the composite panels.

According to the obtained values of the nail withdrawal resistance, the composite panels can be used in construction.

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

1. INTRODUCTION

Composite wood-based panels represent a type of wood-based panels made as combination of particleboard and veneers. When peeled veneers are used for particleboard overlay, a possibility for production of structural panel with high physical and mechanical properties is created. This kind of panel can meet the requirements of modern construction.

The research of composite wood-based panels was carried out by many authors (Buyuksari 2012; Dimeski et al. 1996 and 1997; Hse et al. 2012; Iliev et al. 1994, 2000, 2005, 2010; Jakimovska Popovska et al. 2014; Jakimovska Popovska et al. 2015; Jakimovska Popovska and Iliev, 2015; Miljković et al. 1997; Mihajolva et al. 2005; Norvydas and Minelga 2006).

One part of the research is concerned with the dimensional stability of the panels under water impact (Iliev 2005; Mihajolva et al. 2005; Jakimovska Popovska et al. 2014). Possibilities for improving the water resistance properties of composite panels were investigated by Hse et al. 2012. Iliev (2000) and Norvydas and Minelga (2006) studied the impact of veneer number on the properties of composite panels.

Besides other mechanical properties, the nail withdrawal resistance is an important property of composite wood-based panels for use in construction, which can show the behavior of the assemblies of this kind of wood-based panels made with nails. The strength and stability of the structures made from particleboards depend very much on the fastening that holds the parts of the structure together (Miljković and Popović, 2004).

The aim of the research presented in this paper is to study nail withdrawal resistance of composite wood-based panels made from particleboard core overlaid on both sides with two-ply cross-laminated veneers from different wood species.

2. MATERIALS AND METHODS OF THE EXPERIMENTAL WORK

For realization of the research, 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 represents a single-layer particleboard with thickness of 16 mm which was overlaid on both sides with two-ply cross-laminated veneers 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.

The single-layered particleboards were made from beech particles. Water solution of phenol-formaldehyde resin was used as an adhesive for particle bonding. The resin has a density of 1,22 g/cm^3 at 20°C; 50,43% dry matters content, 0,30% content of free phenol, viscosity of 195 s by Ford at 20°C, pH value – 11,0 and resin curing time of 97 s. For production of single-layered particleboards, a pure phenol formaldehyde resin with 16 % dry matters content on dry wood basis was used. The mixture of particles for production of single-layered particleboards is obtained with mixing of equal weight ratios of particles for core and surface layer.

The particleboards were pressed under specific pressure of 25 kg/cm^2 (19 minutes under maximal specific pressure of 25 kg/cm^2 and 10 minutes under pressure of 12,5 kg/cm^2) at temperature of 155°C and pressing time of 30 minutes. The particleboards were made with dimensions of 560×455 mm^2 and thickness of 16 mm.

The particleboard overlay was made with two veneer sheets on each side of the panels. 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 dry matters content of 48,85% 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 on 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 the following parameters: 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. Panel's overlaying with this paper was made in order to improve the water resistance of composite panels which were intended for use in construction. The produced panels have dimensions of 545×435 mm^2, with thickness from 23,00 to 23,37 mm depending on the model and moisture content of 8,5 %.

Applying 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 panels' structure is shown in figure 1.

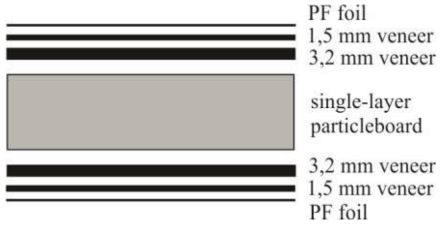

Figure 1. *Pattern of the structure of composite panels*

The nail withdrawal resistance of composite panels was tested according to MKS D.C8.111/82. This property was tested in two directions: perpendicular to the plane of the panel, i.e., when the nail was driven into the surface of the panel and into the plain of the panel (the nail was driven in panel's edge). Nine test specimens of each model were made with dimensions of 100×50×d mm. Nails with diameter of 2 mm and length of 45 mm were used for these tests. When the nails were driven into the surface of the panel, the free length of the nail above the surface of the test specimen was 4/10 of nail's length, while when the nails were driven into the edge of the panel, the depth of the nail driving into the test specimen was 1,2×d. Because of the limited number of test specimens, the same test specimens were used for testing the withdrawal resistance in both directions of the panel, so one nail was driven into the surface of the test specimen and two nails into the edge of the specimen.

The tests were performed on universal testing machine, measuring the maximal force of withdrawal.The specific nail withdrawal resistance perpendicular to the plane of the panel was calculated using the following equation:

$$K_{\perp} = \frac{F}{d \times \pi \times d_1} \text{ [N/mm}^2\text{]},$$

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

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

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

where F is maximal force of nail withdrawal [N]; d is diameter of the nails [mm] and l is the depth of driving of the nail in to the panel's edge.

The test specimens for determination of nail withdrawal resistance are shown on figures 2 and 3.

Figure 2. *Test specimens for determination of nail withdrawal resistance parallel to the plane of composite panels*

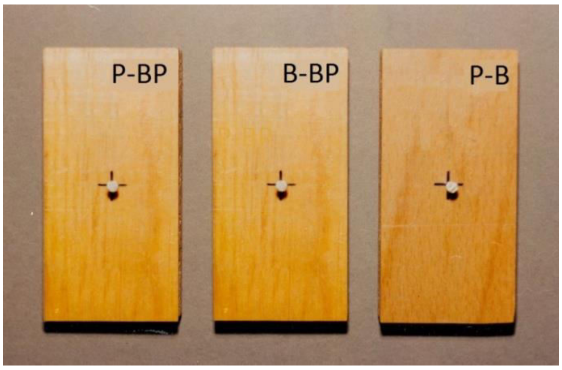

Figure 3. *Test specimens for determination of nail withdrawal resistance perpendicular to the plane of composite panels*

The data obtained was statistically analyzed. One way ANOVA was used to determine the significance of the effect of veneer overlay on panel's nail withdrawal resistance perpendicular to the plane of the panel. Shapiro-Wilk test for normality of the obtained data was applied and Levene's test for homogeneity of variances was applied. Tukey's test was applied to evaluate the statistical significance between mean values of the property of composite panels with different combination of veneer overlay (different panel models).

Statistical software SPSS Statistic was used for statistical analysis of the obtained data.

3. RESULTS AND DISCUSSION

The results for the density of composite panels are shown in Table 1. The ANOVA (F(2,24) = 4,583; p = 0,021) and Tukey's test for the density of the composite panels showed that there are statistical differences in the density of the composite model made with beech and black pine veneers (model B-BP) compared to the model made with poplar and black pine veneers (model P-BP). The highest mean value of density was achieved in composite model B-BP (723,22 kg/m^3), while the lowest value was achieved in model P-BP (690,00 kg/m^3).

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/m^3	*kg/m^3*	*kg/m^3*	*Lower Bound*	*Upper Bound*	*kg/m^3*	*kg/m^3*
B-BP	9	723,22^a	692,00	747,00	708,51	737,93	19,14	6,38
P-BP	9	690,00^b	656,00	720,00	671,97	708,03	23,45	7,82
P-B	9	712,67^{a,b}	673,00	757,00	691,18	734,16	27,96	9,32

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

The results for the nail withdrawal resistance perpendicular to the plain of the panels are shown in Table 2. The analysis of variance of the data obtained for nail withdrawal resistance perpendicular to the plain of the panel (ANOVA: F (2; 24) = 4,391; p = 0,024) showed that the differences between the mean value of this property of at least two models are statistically significant, which means that the 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 model P-BP and the other two composite models (B-BP and P-B). The differences in the mean values of nail withdrawal resistance perpendicular to the plain of the panel between model B-BP and model P-B are not statistically significant.

Higher mean value of this property was achieved in composite models that have beech veneers in its structure (models B-BP and P-B), while the lowest value was achieved in model P-BP. These values correspond with the values of the density of the composite models.

Table 2. *Statistical data for nail 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/mm^2	*N/mm^2*	*N/mm^2*	*Lower Bound*	*Upper Bound*	*N/mm^2*	*N/mm^2*
B-BP	9	4,82^a	4,27	5,56	4,43	5,21	0,50	0,17
P-BP	9	4,20^b	3,92	4,51	4,04	4,35	0,21	0,07
P-B	9	4,83^a	4,12	6,61	4,28	5,39	0,72	0,24

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

The results for the nail withdrawal resistance parallel to the plain of the panels are shown in Table 3. The analysis of variance of the data obtained for nail withdrawal resistance parallel to the plain of the panel (ANOVA: F (2; 24)=13,661; 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 of 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.

Table 3. *Statistical data for nail 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	2,29[a]	2,09	2,49	2,18	2,40	0,14	0,05
P-BP	9	2,73[b]	2,03	3,26	2,36	3,11	0,49	0,16
P-B	9	3,14[c]	2,67	3,72	2,90	3,39	0,32	0,11

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

The obtained values of nail withdrawal resistance of the experimental composite panels are within the limits of the values listed in the available literature from similar researches. Miljković et al. (1997) give the value of 4,72 N/mm^2 for nail withdrawal resistance perpendicular to the plain of the composite panel made with two-ply cross-laminated black pine veneers. Dimeski et al. (1997) give the value of 4,04 N/mm^2 for nail withdrawal resistance parallel to the plain of the composite panels made with two-ply cross-laminated poplar veneers. Iliev (2000) gives the values in the limits of 4,39 to 5,62 N/mm^2 for nail withdrawal resistance perpendicular to the plain of the composite panels made with two-ply cross-laminated beech veneers. The same author for the nail withdrawal resistance parallel to the plain of the composite panels made with two-ply cross-laminated beech veneers gives the values within the limits of 2,70 to 3,91 N/mm^2. Jakimovska Popovska and Iliev (2015) for the nail withdrawal resistance perpendicular to the plain of the composite panel made with two-ply cross-laminated veneers give the values in the limits of 4,04 to 5,68 N/mm^2.

Miljković (1991) defined the values within the limits of 2,4 to 3,6 N/mm^2 for the nail withdrawal resistance perpendicular to the plain of the particleboard panel and the values within the limits of 1,2 to 1,8 N/mm^2 for the nail withdrawal resistance parallel to the plain of the particleboard panel. The obtained values for this property of the experimental composite wood-based panels exceed these values.

4. CONCLUSIONS

On basis of the results obtained from the research conducted it can be concluded that composite wood-based panels made with peeled constructive veneers for particleboard overlay are adequate for structural application in construction.

The different wood species and its combination used for particleboard overlay have significant impact on the values of nail withdrawal resistance perpendicular to the plain of the composite panels. The higher mean value of this property is achieved in composite models that have beech veneers in its structure, which is in accordance with the values of the density of the panels.

According to the obtained values of nail withdrawal resistance, the composite panels can be used in construction.

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