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

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ABSTRACT

This research includes the screw withdrawal resistance of wood-based composite panels for use in the construction.

Three experimental wood-based composite panels were prepared by combining particleboards and peeled beech, black pine and poplar veneers with thickness of 3.2 mm. The core layer of the wood-based composite panels was made of single-layer particleboard with the thickness of 16 mm, which was overlaid on both sides with the veneers.

Water-soluble phenol-formaldehyde resin was used for particle bonding and veneering. The screw withdrawal tests were performed according to the principles of the standard MKS D.C8.112/82. The screw withdrawal resistance was tested in two directions: perpendicular to the plane of the panel, and in plain of the panel.

The results from the research showed that the different veneer species used for particleboard overlay significantly affected the screw withdrawal resistance perpendicular to the plain of the wood-based composite panels.

According to the obtained the screw withdrawal resistance values, wood-based composite panels tested in this study could be recommended for utilizing in the construction of wooden structures.

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

1. INTRODUCTION

The researches in the area of wood-based panels for structural use are directed to creating possibilities and finding methods for production of stable panels with high physical and mechanical properties that can meet the requirements of the modern construction. Such type of stable panel for use in construction is composite wood-based panels, which represent a composition of particleboard and veneers (particleboard core overlaid with peeled veneers). These panels combine structural efficiency with favorable manufacturing cost (Biblis and Chiu, 1974).

Many authors have done researches on the properties of composite panels made from various core and face materials (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, 2015).

Some of the researches concern the dimensional stability of the panels under water impact (Iliev, 2006; Jakimovska Popovska et al., 2014; Mihajolva et al., 2005). Possibilities for improving the water resistance properties of composite panels were investigated by Hse et al. (2012).

The impact of the number of the veneers on composite panel's properties was studied by Iliev (2000) and Norvydas and Minelga (2006).

Beside other physical and mechanical properties of composite wood-based panels that are important for panels use in construction, the screw withdrawal resistance is also an important property that can shows the behavior of the assemblies of this kind of wood-based panels made with screws. 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).

Many authors had studied the screw holding performance of wood-based materials including particleboards, OSB, MDF and plywood (Eckelman, 1975 and 1988; Miljković et al., 2007; Erdil et al., 2002; Điporović-Momčilović et al., 2006).

This kind of studies can be used to develop estimates of face and edge screw holding strength that can be used in the product engineering of constructions made from wood-based materials.

This research comprises the screw withdrawal resistance of wood-based composite panels made with single veneer overlay on both sides of a particleboard. Other part of the study will be the research of a screw withdrawal resistance of a wood-based composite panels made with two-ply cross laminated veneers.

2. MATERIALS AND METHODS

2.1. Preparation of the Wood-based Panels

Three experimental wood-based composite panels were produced in the scope of the study. The wood-based composite panels were made by combining single-layer particleboard with thickness of 16 mm as core layer and peeled beech, black pine and poplar veneers with thickness of 3.2 mm as surface layers (Fig. 1).

The single-layered particleboards were made from beech particles with mixing of equal weight ratios of particles for core and surface layer. Water solution of phenol-formaldehyde resin was used as an adhesive for particle bonding. The characteristics of the resin and pressing parameters used for particleboard preparation are presented in table 1. For production of single-layered particleboards, a pure phenol formaldehyde resin with 16% dry matters content on dry wood basis was used.

Table 1: Resin characteristics and pressing parameters used for particleboard preparation

Resin characteristics	
Color	Light red
Density at 20°C	1.22 g/cm^3
Dry matters	50.43%
Content of free phenol	0.30%
Viscosity by Ford at 20°C	195 s
pH value	11.0
Resin curing time	97 s
Pressing parameters	
Specific pressure	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)
Pressing temperature	155°C

Pressing time	30 minutes

The particleboards were made with dimensions of 560×455 mm^2 and thickness of 16 mm.

The particleboard overlay was made with beech, black pine and poplar veneers with thickness of 3.2 mm. The orientation of the veneers was parallel to the longitudinal axis of the particleboard. A water-soluble phenol-formaldehyde resin with the following characteristics was used for veneer bonding: color – light red; density at 20 °C – 1.201 g/cm^3; dry matters – 48.85%; content of free phenol – 0.21%; viscosity by Ford at 20 °C – 165 s; pH value – 11.12; resin curing time (120 °C) – 108 s. 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 particleboards 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 had dimensions of 545×435 mm^2, with thickness 20 mm and moisture content of 8.5%.

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

- model A: water-resistant composite panel made of particleboard core layer and face layers of beech peeled veneers;
- model B: water-resistant composite panel made of particleboard core layer and face layers of black pine peeled veneers;
- model C: water-resistant composite panel made of particleboard core layer and face layers of poplar peeled veneers.

The configuration of panels' structure is shown on Figure 1.

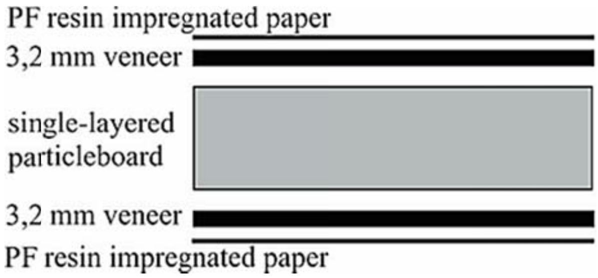

Figure 1: Pattern of the structure of composite panels

2.2. Screw Withdrawal Resistance Tests

The screw withdrawal resistance of wood-based composite panels was tested according to MKS D.C8.112/82. Screw withdrawal resistance 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 the standard DIN 97 were used for these tests. The screws had the following technical parameters: thread diameter – 4 mm, length – 40 mm, threaded pitch – 1.8 mm, thread core diameter – 2.8 mm, diameter of unthreaded shank – 4 mm, head diameter – 7.5 mm, head height – 2.2 mm and width of the slot – 1 mm. The screw holes with diameter of 2.5 mm and depth of d_1 – 2 mm (where d_1 is panel's thickness) were pre-drilled in the panels for screw driving into the surface of the panel.

When the screws were driven in to the edge of the panel, the holes with diameter of 2 mm and the depth of 25 mm were pre-drilled.

Because of the limited number of the test specimens, the same test specimens were used for testing the withdrawal resistance in both direction of the panel, so one screw was driven in to the surface of the test specimen and two screws in to the edge of the specimen.

The test specimens for determination of screw withdrawal resistance are shown on Figure 2 and 3.

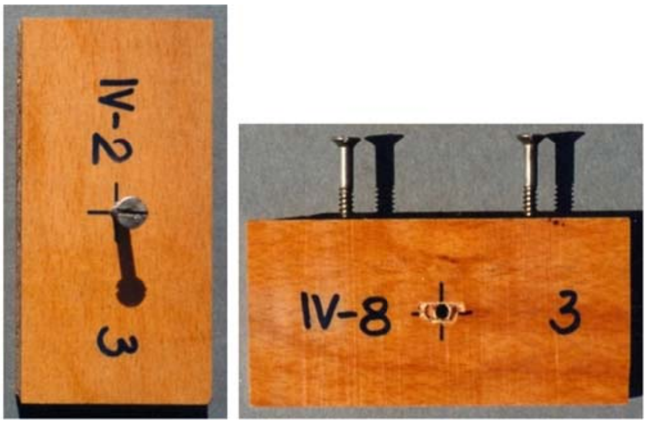

Figure 2: Test specimens for determination of screw withdrawal resistance of composite panels

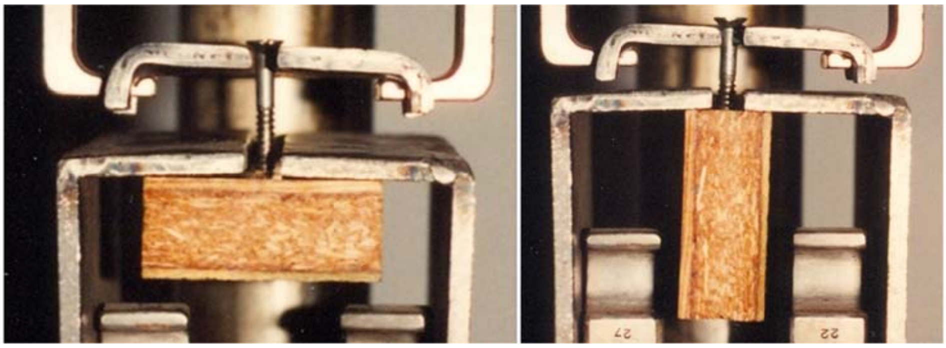

Figure 3: Determination of screw withdrawal resistance of composite panels

The tests were performed on universal testing machine, measuring the maximal force of withdrawal. The loading rate was 2 mm/min.

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

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

where F is maximal force of screw withdrawal [N], d is 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:

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

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

2.3. Statistical Evaluation

The obtained data were statistically analyzed. One way ANOVA was used to determine the significance of the effect of veneer type on panel's screw 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 veneer type (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 2. The highest density of composite models is achieved in model A, i.e. in model overlaid with beech veneers. The ANOVA ($F(2; 24)=6.071$; $p=0.007$) and Tukey's test for the density of the composite panels showed that there is statistical differences in the density of the composite model made with beech veneers and poplar veneers. The differences between the density of composite panel made with beech veneers and composite panel made with black pine veneers are not statistically significant.

The analysis of variance of the obtained data for the screw withdrawal resistance perpendicular to the plain of the panel (ANOVA: $F(2; 24)=4.46$; $p=0.023$) 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 models A and B. The differences in the mean values of screw withdrawal resistance perpendicular to the plain of the panel between model B and model C, as well as between models A and C are not statistically significant.

The highest mean value of this property is achieved in composite model that is overlaid with beech veneers, while the lowest value is achieved in model made with black pine veneers, with the notation that the differences between the model made with black pine veneers and that one made with poplar veneers are not statistically significant.

The analysis of variance of the obtained data for the screw withdrawal resistance parallel to the plain of the panel (ANOVA: $F(2; 24)=0.185$; $p=0.832$) showed that there are no statistically significant differences between the mean values of this property of all composite models. This was expected due to the fact that all composite models were made with the same core layer of single-layer particleboard, i.e., in all models the screw withdrawal resistance parallel to the plain of the panel is tested in the particleboard core layer, which is the same in all models.

Table 2: 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*
A	9	723.11[a]	703.00	739.00	712.90	733.32	13.28	4.43
B	9	699.56[a.b]	654.00	768.00	673.43	725.68	33.99	11.33
C	9	673.00[b]	614.00	718.00	643.59	702.41	38.26	12.75

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

Table 3: 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*
A	9	13.00[a]	12.28	14.59	12.45	13.55	0.71	0.24
B	9	11.12[b]	8.68	14.32	9.83	12.40	1.67	0.56
C	9	11.60[a.b]	8.62	13.54	10.38	12.82	1.58	0.53

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

Table 4: 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*
A	9	2.70	2.39	3.03	2.50	2.90	0.26	0.09
B	9	2.61	2.11	3.06	2.35	2.86	0.34	0.11
C	9	2.71	2.13	3.59	2.27	3.16	0.57	0.19

There are no statistically significant differences between the mean values 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 from the similar researches. 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 of the composite panels made with single beech veneer overlay and values within the limits of 9.69 to 12.95 N/mm^2 for composite panels made two-ply cross-laminated beech veneers. 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.

For the screw withdrawal resistance parallel to the plain of the panel Iliev (2000) gives the values within the limits of 5,42 to 7.92 N/mm^2 for composite panels made with single beech veneer overlay and values within the limits of 4.19 to 7.21 N/mm^2 for composite panels made with two-ply cross-laminated beech veneers.

According to Miljković (1991) the screw withdrawal resistance perpendicular to the plain of the particleboard panel is higher for 100 to 125% compared to the screw withdrawal resistance parallel to the plain of the particleboard panel. The screw withdrawal resistance perpendicular to the plain of the particleboard increases proportionally with the increment of the particleboard density, while the edge withdrawal resistance depends on the quality of the bonds between particles (Miljković, 1991).

4. CONCLUSIONS

On the basis of the obtained results from the conducted research, following conclusions can be drawn:

- The obtained results for the screw withdrawal resistance of the experimental panels showed that the composite wood-based panels made with peeled constructive veneers for particleboard overlay are adequate for structural application in construction.

- The wood specie used for veneer production (beech, black pine or poplar) 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 veneer overlay, which is in accordance with the highest value of the density of this model.
- According to the obtained values of the screw withdrawal resistance, the composite panels can be used in construction.

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