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IMPACT OF RESIN CONTENT ON COMPRESSIVE STRENGTH AND JANKA HARDNESS OF COMPOSITE WOOD-BASED PANELS

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ABSTRACT

The aim of the research presented in this paper is to study the impact of resin content on compressive strength and Janka hardness of composite wood-based panels.

For this purpose three experimental models of composite wood-based panels were made that represent a combination of particleboards and constructive veneers. The core layer of composite panels was made of single-layer particleboard with thickness of 16 mm. Particleboards were overlaid on both sides with beech peeled veneer with thickness of 3,2 mm.

Water-soluble phenol-formaldehyde resin with 10 %, 13 % and 16 % dry matters content on dry wood basis was used respectively for production of single-layer particleboard cores of the three composite models. The resin used in all three models was modified with epoxy resin.

The veneers were bonded on the particleboard core with the same resin that was used for particle bonding, but without modifier.

Tests for compressive strength were carried out according to MKC DA1.110.

The results from the research showed that the resin content in particleboard core has significant impact on the values of compressive strength of composite wood-based panels.

Key words: resin content, composite wood-based panels, particleboard, veneers, water-soluble phenol-formaldehyde resin, modifier, compressive strength, Janka hardness.

1. INTRODUCTION

Composite wood-based panel is made as a combination of particleboard core, overlaid with peeled veneers which combine structural efficiency with favorable manufacturing cost (Biblis and Chiu, 1974). These panels can be used in structural application in construction.

The properties of overlaid particleboards are influenced by the number of the veneer layers used for particleboard overlay (Norvydas and Minelga, 2006). Buyuksari (2012) studied the effect of thermally compressed veneers for production of overlaid particleboard for structural application.

Properties of composite panels made from various core and face materials were investigated by many authors (Hse, 1976; Hse *et al.*, 2012; 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).

The resin content in particleboards has impact on its properties. The type and amount of resin used can also affect the quality of wood composites including composite wood panels. The quality of particleboard is increased by increasing the resin content due to better distribution of resin on the wood particles and increasing the connection points between wood and resin (Dahmardeh Ghalehno *et al.* 2013).

The effect of resin content on particleboard properties was studied by Jazayeri *et al.* (2007). The study conducted by Kasim *et al.* (2018) as well as by Maraghi *et al.* (2018) showed that dimensional stability of particleboards was improved by increasing the resin content.

The aim of the research presented in this paper is to study the impact of resin content on compressive strength parallel to the plane of composite wood-based panels and janka hardness.

2. MATERIALS AND METHODS OF THE EXPERIMENTAL WORK

Three experimental models of composite wood-based panels were made that represent a combination of particleboards and peeled veneers. The core layer of composite panels was made of single-layer particleboard with thickness of 16 mm which was overlaid on both sides with beech peeled veneer with thickness of 3,2 mm.

The single-layer particleboard was made from beech particles (with small amounts of elm and poplar particles) mixed from particles for core and surface layer for production of standard three-layer particleboards. The volume ratio of the particles for core layer and surface layer was 8:2. The following ratios of particle fractions were used: 0/2,5 mm (26 %), 2,5/0,63 mm (63 %), 0,63/0,36 mm (6 %), 0,36/0,16 mm (3 %) and 0,6/0,07 mm (2 %). Moisture content of the mixed particles determined by gravimetric method was 2,9 %.

Water solution of phenol-formaldehyde resin with 47,30 % dry matter content was used as an adhesive for particle bonding. The characteristics of the resin and pressing parameters used for manufacture of the single-layer particleboards are described in previous paper (Jakimovska Popovska and Iliev, 2021).

Three models of single-layer particleboards were made with different resin content. For production of single-layer particleboards, phenol formaldehyde resin with 10 % 13 % and 16 % dry matters content on dry wood basis was used, modified with epoxy resin with 5 % dry content. Aluminum sulfate $Al_2(SO_4)_3$×18H2O was used as catalyst with quantity of 1 % dry matters content on dry adhesive basis.

The particleboards were pressed under specific pressure of 25 kg/cm^2. The panels were made with dimensions of 550×550 mm^2 and thickness of 16 mm.

The veneers with moisture content of 7,2 % were bonded on the core layer of particleboard with the same resin that was used for particle bonding, but without modifier. Wheat flour was used as filler and 20 % solution of NaOH as catalyst. The binder was applied in quantity of 180 g/m^2 on both sides on the particleboards.

The composite panels were made in a hot press under specific pressure of 15 kg/cm^2 at temperature of 155°C for a period of 8 minutes.

Dimensions of the composite panels were 540×540 mm^2. The moisture content of the panels was 10 %.

The denotations of the experimental composite models have the following meaning:

- model C10: composite panel made of particleboard core with 10 % resin content (dry matters content on dry wood basis) overlaid on both sides with beech peeled veneer with thickness of 3,2 mm (d=21,26 mm; γ=786,36 kg/m^3);
- model C13: composite panel made of particleboard core with 13 % resin content (dry matters content on dry wood basis) overlaid on both sides with beech peeled veneer with thickness of 3,2 mm (d=21,38 mm; γ=798,67 kg/m^3);
- model C16: composite panel made of particleboard core with 16 % resin content (dry matters content on dry wood basis) overlaid on both sides with beech peeled veneer with thickness of 3,2 mm (d=21,33 mm; γ=793,97 kg/m^3).

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

The compressive strength parallel to the plane of the experimental panels were tested according to MKC DA1.110 on the test specimens with dimensions of 50×100×d mm. Compressive force was applied on the long edge of the test specimens, whereas the direction of the compressive force was perpendicular to the face grain of the panel.

Janka hardness of the experimental composite panels was tested on the test specimens with dimensions of 100×100 mm. The tests were performed at two measuring points, positioned on the face and the back of the test specimens. Hardness was tested by pressing a stainless hemisphere on the surface of the test specimen, which, when entering the surface of the test specimen leaves an impression in the form of a calotte with an area of 1 cm^2. The ratio between the force used and the surface of the calotte represents the hardness of the panel.

The data obtained were statistically analyzed. One way ANOVA was used to determine the significance of the effect of resin content in the particleboard core on the compressive strength and hardness of composite panels. Tukey's test was applied to evaluate the statistical significance between mean values of the properties of different panel models.

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

3. RESULTS AND DISCUSSION

The test results for the compressive strength of experimental composite panels are shown in Tables 1, 2 and 3.

The results obtained from the tests of compressive strength showed that the highest mean value of this property is achieved in the model made with 16 % resin content in particleboard core (C16). The mean values of models C10 and C13 are lower by 25,3 % and 8,55 %, respectively.

Table 1. *Statistical values for compressive strength of composite panels*

Model	***N***	***Mean (%)***	***Std. Deviation (%)***	***Std. Error (%)***	***95% Confidence Interval for Mean (%)***		***Min (%)***	***Max (%)***
					Lower Bound	***Upper Bound***		
C10	6	16,42^{a}	2,04	0,83	14,28	18,56	13,41	19,53
C13	6	20,10^{a,b}	2,25	0,92	17,74	22,46	16,14	22,25
C16	6	21,98^{b}	4,69	1,91	17,05	26,90	14,32	26,48

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

The analysis of variance of the obtained data for the compressive strength (ANOVA: F (2; 15)=4,612; p=0,027) showed that the differences between the mean value of this property of at least two models are statistically significant, which means that the resin content in particleboard core has considerable impact on the values of 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 only between models C10 and C16. The difference in the mean values between model C13 and model C10, as well as between models C13 and C16 is not statistically important. This shows that increasing the resin content from 10 % to 13 % does not appreciably increase the value of compressive strength.

Table 2. *Anova for significance of the effect of resin content on compressive strength*

ANOVA

Janka Hardness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	95,967	2	47,984	4,612	0,027
Within Groups	156,066	15	10,404		
Total	252,034	17			

The values of compressive strength are within the limits and higher compared to the values for this property listed in available literature. Dimeski *et al.* (1996) gives the value of 15,52 N/mm^2 for composite panels single-veneered on both sides with beech veneers. Dimeski *et al.* (1997) gives the value of 13,23 N/mm^2 for composite panels single-veneered on both sides with poplar veneers. Miljokić *et al.* (1997) gives the value of 13,82 N/mm^2 for composite panels single-veneered on both sides with pine veneers.

The high values of this property showed that these panels can be used as nonstructural and structural elements in construction.

Table 3. *Tukey's test for statistical significance between the mean values of compression strength of different composite models*

Model		N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a]	C-10	6	16,416667	
	C-13	6	20,101667	20,101667
	C-16	6		21,975000
	Sig.		0,152	0,585

The test results for Janka hardness of experimental composite panels are shown in Tables 4 and 5.

The obtained results from the tests of Janka hardness showed that the highest mean value of this property is achieved in the model made with 13 % resin content in particleboard core (CP13). The mean values of models C10 and C16 are lower by 4,7 % and 3,5 %, respectively.

Table 4. *Statistical values for Janka hardness of composite panels*

Model	***N***	***Mean (%)***	***Std. Deviation (%)***	***Std. Error (%)***	***95% Confidence Interval for Mean (%)***		***Min (%)***	***Max (%)***
					Lower Bound	***Upper Bound***		
C10	6	81,54	13,00	3,75	73,28	89,80	65,00	101,50
C13	6	85,58	8,18	2,36	80,39	90,78	70,00	94,00
C16	6	82,58	18,79	5,42	70,65	94,52	50,50	106,50

Table 5. *Anova for significance of the effect of resin content on Janka hardness*

ANOVA					
Janka Hardness					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	105,681	2	52,840	0,269	0,766
Within Groups	6478,063	33	196,305		
Total	6583,743	35			

Analysis of variances of the data obtained for compression strength (ANOVA: F (2; 33)=0,269; p=0,766) showed that there is statistically insignificant difference between all composite models. This indicates that hardness of composite panels is mainly result of hardness of the wood veneers. Resin content in the particleboard core does not cause a substantial difference in the values of composite panels' hardness.

The obtained values of Janka hardness of the experimental composite panels are lower compared to the values of Janka hardenss of particleboards made with 10 and 16% resin content with and withouth modifier Iliev (2000). Iliev (2000) gives the values for Janka hardnes of these particleboards within the limits of 88,17 to 121,17 N/mm^2.

Janka hardness of beech solid wood is within the limits of 54 to 110 N/mm^2 (Lukić-Simonović, 1983). The values of Janka hardness of solid wood affects the values of hardness of composite panels.

4. CONCLUSIONS

Based on the results obtained from the conducted research and presented in this paper it can be concluded that the resin content in particleboard core of composite wood-based panels has a critical impact on the compressive strength parallel to the plane of the panel.

By increasing the resin content from 10 to 16 % there is an increase in the value of compressive strength of the panel.

Increasing the resin content from 10 to 16 % leads to increment in compressive strength of near 34 %.

Resin content in the particleboard core does not cause a significant difference in the values of Janka hardness of the composite panels. The hardness of composite panels is mainly a result of the hardness of the wood veneers.

This kind of research presented in the paper can help in defining the technological parameters for production of composite wood-based panels that can meet the requirements for application as structural or non-structural elements in construction.

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