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RESEARCH ON PHYSICAL AND MECHANICAL CHARACTERISTICS OF FRONT BLOCKBOARDS MADE FROM POST-CONSUMER WOOD

The expediency of using post-consumer wood (PCW) for material production is substantiated. It is proposed to process PCW into blockboards (BB). Proposed are new designs of PCW-made blockboards which are suitable for manufacturing furniture fronts. It was experimentally confirmed that the physical and mechanical properties of front PCW-made blockboards meet the requirements of standards. Obtained are patterns of influence of the width of the core strips of the blockboard and the thickness of the facing wood fiberboard (WFB) on dimensional stability, strength at static bending across the strips and strength in shearing along the glue line of front PCW-made blockboards in the dry state. Adequate regression models are obtained that can be used to describe a study object. Practical recommendations are offered for the production and use of front PCW-made blockboards for furniture production.

Keywords: wood, post-consumer wood (PCW), blockboards (BB), wood fiberboard (WFB), recycling, front surfaces, BB designs, technologies, shape stability, strength.

Relevance of the research. At the beginning of the third millennium, the humanity of the planet started seriously thinking about the environmental problems. These challenges also apply to forest resources, woodworking and furniture industries, secondary wood raw material reserves, postproduction wastes, primary production wood residues, solid household waste and so on.

An additional, unused reserve of wood raw materials in Ukraine is post-consumer wood (PCW) [1-19], the annual potential volume of which is about 2 million tons. In most European countries, the problems of PCW utilization have been partially solved. In Ukraine this issue at the Ministerial level has not been seriously discussed yet. Among scientists and manufacturers of furniture and joinery products, as well as producers of electric and thermal energy, sometimes there is a dilemma – whether to burn PCW or give this wood a «second life».

The scientists of UNFU believe that the future of PCW is its material use [1, 2, 6, 7, 10, 12, 13]. PCW will provide woodworking and furniture enterprises with additional raw materials, reduce the amount of waste accumulation in landfills, improve the environment of settlements, reduce carbon dioxide emissions from burning high-quality PCW, preserve the primary forest resources, which is relevant.

Besides, the involvement of PCW in the creation of wood products will force entrepreneurs to create new technological solutions for the processing of this resource, and scientists - to create new innovative non-standard wood products. All this requires conducting research, testing and confidence in their reasoning, as well as environmental and economic feasibility. Only a comprehensive and rational approach to the use of wood material on the basis of economic and environmental considerations will become effective for the implementation and solving of the main tasks of the country in the field of woodworking.

The problem of research. The problem today in this field is to prove to the producer of Ukraine the expediency of using PCW materially, i.e. for the manufacture of wood products. Today, entrepreneurs are mainly engaged in post-production wood waste, which, unlike European ones, does not cover the whole segment of secondary wood resources, one of which is PCW [14].

The solution of this problem is complicated by the diversity of PCW, the lack of technological solutions, practical recommendations, and the like. Scientists of Ukraine in their writings suggest ways of material use of PCW, in particular for the production of particleboards [3, 9, 11, 18], blockboards [2, 4, 6, 8, 19], the manufacture of elements of structural furniture [1, 7, 10, 12, 13], bended workpieces [15, 16] and others.

The results of their research indicate that this problem has not been completely solved, because the scientific basis and practical recommendations for effective production processes with predicting the properties of PCW-made products have not yet been developed in full [1-13, 15-19].

The implementation of this relevant idea in the production process should be based on the substantiated scientific and technical base of the PCW material resources, the development of resource-saving and environmentally friendly technologies, the development of regime parameters, the formulation of practical recommendations and the establishment of the patterns of impact of the PCW use on the physical and mechanical indices of the obtained products, in particular front blockboards (BBs).

The purpose of the work is to study the feasibility and clarify the specifics of PCW usage in the production of structural components of front blockboards (BBs).

The object of research are front PCW-made blockboards that are faced with thickened wood fiberboards (WFB).

The subject of research are physical and mathematical models, patterns and practical recommendations for the use of PCW in the technology of front blockboards.

The objectives of research:

- to collect PCW;
- to clean PCW which is suitable for material use;
- to make front blockboards from PCW;
- to determine the shape stability of PCW-made blockboards;
- to determine the ultimate static bending strength across the strips;
- to determine the ultimate strength in shearing along the glue line;
- to elaborate practical recommendations for the construction of front PCW-made blockboards.

Materials and designs of front PCW-made blockboards. Blockboards are constructional materials that are made by sandwiching a blockboard core between two sheets of veneer, a thin-walled plywood or sheets of fiberboard (2.5 and 3.2 mm thick). To create experimental front blockboards, WFB sheets of increased standard thickness were used – 4-6 mm (Fig. 1). On the faces of the manufactured PCW-made blockboards, it will be possible to perform milling work and, in the future, to make front surfaces (doors), softforming, postforming.

Fig. 1. Cross-section examples of front blockboards for testing

The following materials were used to make new PCW-made blockboards intended to create front surfaces of furniture products:

- wooden strips of softwood species from used wood products (in particular, window and door frames and cases);
- hard fiberboard (hardboard);
- polyvinyl acetate adhesive (PVA) of the brand Jowat 103.05 D3.

To conduct studies, the designs of PCW-made blockboards were developed, which would be used in the manufacture of front surfaces.

Basic characteristics of new structures of front PCW-made blockboards:

- the thickness of the PCW-made blockboard is 19 mm, which complies with the standard GOST 13715-78 [21];
- the width of the core strips is from 20 to 40 mm, which complies with the standard GOST 13715-78;
- gluing strips by straight joints into a blockboard core;
- increased thickness of the fiberboard for facing the blockboard core, in particular 4.0; 5.0; 6.0 mm, the sizes of which comply with the standard GOST 4598-86 [25]. This is determined by the need for milling works for front surfaces on both the faces and the edges of the PCW-made blockboards.

Developed were designs for PCW-made blockboards of 3 groups according to their thickness , and of 9 types according to the width of the core strips:

- the thickness of the fiberboard is 4 mm, the width of the strips is 20; 30; 40 mm (Fig. 2);
- the thickness of the fiberboard is 5 mm, the width of the strips is 20; 30; 40 mm (Fig. 3);
- the thickness of the fiberboard is 6 mm, the width of the strips is 20; 30; 40 mm (Fig. 4).

The laying of strips during the formation of blockboard core was done with consideration for the grain slope, that is, on the principle of alternation, where the main was radial slope with an angle of 60 to 90 degrees.

General methodology of research. To achieve the objectives, a comprehensive methodology was developed that includes the following logical developments:

- methods of manufacturing front PCW-made blockboards;
- methods for determining the shape stability of PCW-made blockboards;
- methods for determining physical and mechanical characteristics of PCW-made blockboards.

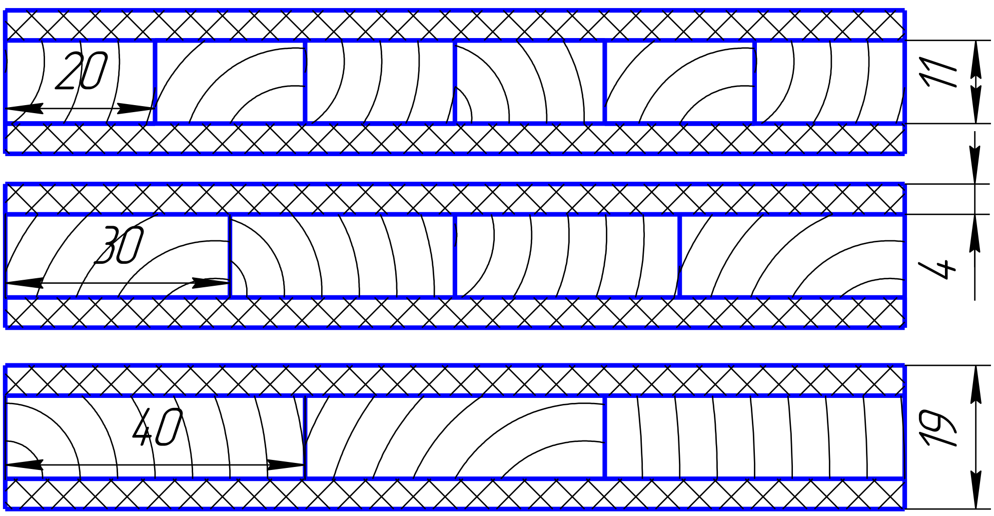

Fig. 2. PCW-made blockboards structures faced with WFB 4 mm thick

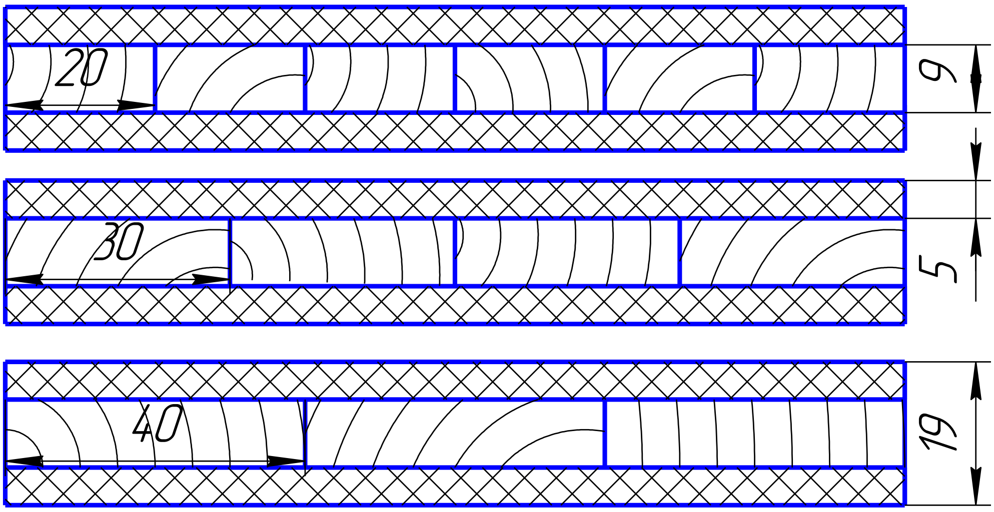

Fig. 3. PCW-made blockboards structures faced with WFB 5 mm thick

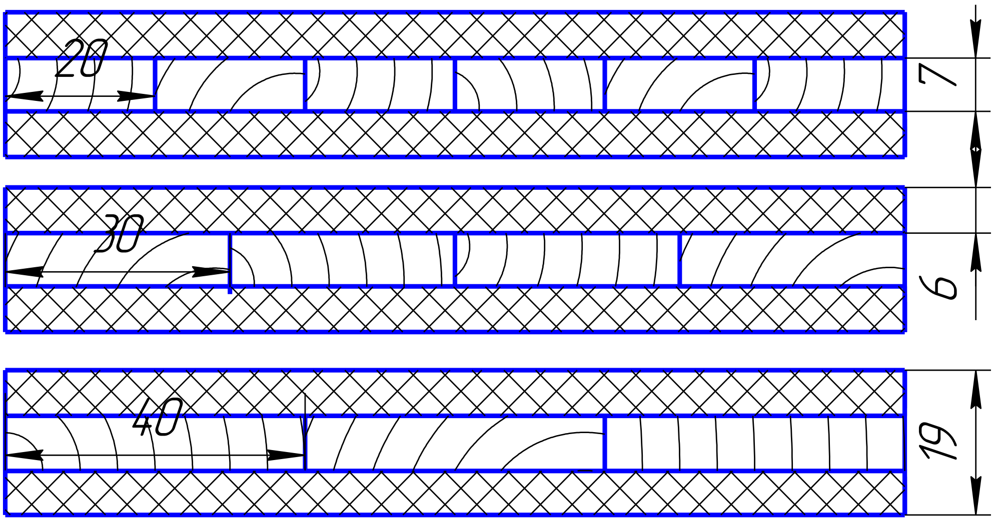

Fig. 4. PCW-made blockboards structures faced with WFB 6 mm thick

Methods of manufacturing front PCW-made blockboards. Since the research was based on the study of the influence of the characteristics of the BB structural components on the shape stability and the physical-and- mechanical characteristics of the blockboards obtained, a B-plan of the second order was implemented (Table 1).

Also, an additional experiment was conducted in the center of the plan. The number of duplicated experiments is 3 for each type of facing: plywood and WFB. A total of 9 types of PCW-made blockboards were fabricated in order to implement the experimental investigations based on the type of facing material (Figs. 2-4).

The prepared strips from solid pine ($B_{PCW)}$ were made 20, 30 and 40 mm wide.

In each blockboard core were presented strips of the same width.

Each of the variant blockboard core was faced fiberboard (H_{WFB}) 4.0, 5.0, and 6.0 mm in thickness.

Constant factors in this study of manufacturing front PCW-made blockboards were as follows: relative humidity – 60-65 %; air temperature – 18-20 ºC; atmospheric pressure – 736 mm Hg; the air circulation velocity – v ≈ 0 m/s; the level of airborne dust; Jowacol 103.05 PVA adhesive; method of application (roll); press temperature; press time; pressure; equipment; volume of the room.

Table. 1. Planning matrix for B-plan with two variables

Experiment No.	Input factors values in the experiment			
	in natural value		in coded value	
	B_{PCW}, mm	H_{WFB}, mm	x_1	x_2
1	20	4	-1	-1
2	40	4	1	-1
3	20	6	-1	1
4	40	6	1	1
5	20	5	-1	0
6	40	5	1	0
7	30	4	0	-1
8	30	6	0	1
9	30	5	0	0

Front PCW-made blockboards technology. The general production process for obtaining PCW-made blockboards can be divided into several stages:

- preparation of the core strips made from PCW;
- cutting of panel woodfiberboard components of blockboards;
- manufacturing the core;
- manufacturing the PCW-made blockboard.

The preparation of wooden strip components of blockboards involves PCW cleaning from fittings and other foreign matter, destruction of finger joints and cutting out defective spots, cleaning wood surfaces from paint and varnish materials, face planing, wood ripping, double-surface milling of edges, trimming to a length of 480 mm.

Preparation of facing decks from WFB involves dimension cutting into a size of 520×520 mm.

Obtaining of blockboard core involves selection of strips according to the strip width, annual rings angle, applying glue to the strips edges with the glue spread of 200-250 g/m^2, clamp bonding (operation parameters: temperature – 85-90 °C; soaking time – 30-40 min; pressure – 0.5-1.0 MPa), technological conditioning (humidity – 60±5 %; temperature – 20±2 °C) for 8-12 hours; double-side milling up to 11, 9, 7 mm respectively for WFB with a thickness of 4.0; 5.0; 6.0 mm; dimension cutting into a size of 480×480 mm.

The final stage of blockboard manufacturing comprises the following steps: application of glue to the blockboard core with glue spread of 150-200 g/m^2, the formation of package, facing in a flat press (operation parameters: temperature – 115-120 °C; press time – 4-6 min; pressure – 1.2-1.3 MPa) technological conditioning (humidity – 60±5%; temperature – 20±2°C) for 4-8 hours; cutting on the perimeter into dimension of 440×440 mm.

Methods for determining shape stability of front PCW-made blockboards.

According to the requirements of the standard GOST 13715-78, warpage of the blockboard can be no more than 1.5-2.5 mm, and rippling – 0.2-0.6 mm

The rippling of boards is determined by the maximum depth of the wave on the surface of the board which is measured with an error of no more than 0.05 mm by indicator of the type ICH-10 (ИЧ-10), according to GOST 577-68, fixed to the ruler slider, it is applied to the board across the core strips at a distance of 200 mm from the edges and in the middle of the length of the board, or by another measuring instrument that provides the required measurement accuracy.

Warping of a blockboard is determined by the amount of the board sag, referred to 1 m of the length of the board diagonal, placed on the verified horizontal surface. The easiest way is to measure the sag with an error of no more than 0.1 mm by using the ICH-10 type indicator, according to GOST 577-68, mounted on a ruler slider, and which is placed along the board diagonal, or by another measuring instrument that provides the required measurement accuracy.

However, having a Computer Numerical Control Unit (CNC) for determining planeness in our laboratory, (Fig. 5), the deflection S, as one of the main characteristics of the shape stability, was measured directly by this unit immediately after the technological conditioning and under the same ambient conditions.

Fig. 5. CNC experimental set-up for determining shape stability of PCW-made blockboards

The numeric readings of the IGC-(3)-25-0.01 indicator (readings are obtained to an accuracy of 0.001 mm) were read with the help of the Microtech Excel company software, type UIC-P1-SOM which was transferred to the Microsoft Excel environment for recording. The readings from BB experimental specimens were taken in two directions: the direction along the grain-direction A, (along the length of BB strips), the direction across the grain-direction B (across the width of the blockboards). The measurements in each direction on the PCW-made blockboards were performed along 10 conventional lines, that is for a total of 20 imaginary lines with a pitch between them being 40 mm (Fig. 6). As a result of measurements, 380 to 440 points were recorded for each line.

Thus, one set of measurements resulted in sampling population of 7.600 to 8.800 (20×(280…440)). The sag value took the average value of this sampling population.

The experimental value of response function was obtained as a difference of the average values of samples obtained in the first and the last measurement (in absolute value). The results are presented in Table 2. The second set of measurements was performed 7 days after the date of the manufacture of experimental specimens of PCW-made blockboards. The measurements were performed once a week. The last set of measurements was taken on the sixth week, the amount of sag for this measurement did not differ from the previous one by more than 5%. Thus, six sets of measurements were performed during the study on shape stability of PCW-made blockboards. The value of the sag was determined as the difference between the first and the sixth experiment.

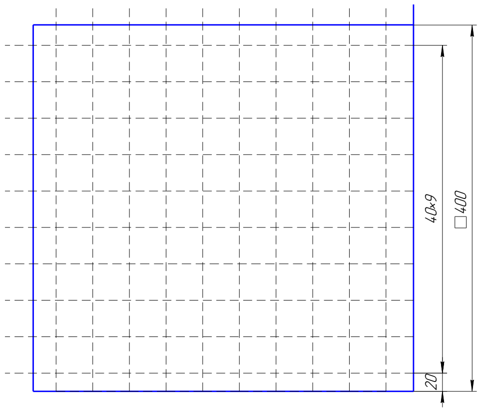

Fig. 6. Scheme of motion trajectory of the numerical indicator on the plane of the blockboard

Methods for determining of physical-and-mechanical properties of front PCW-made blockboards. According to the requirements of GOST 13715-78, the following parameters were subject to control:

- static-bending strength across strips;
- shearing dry strength along the glue line;

Test specimens for determination of static bending strength across strips were made according to GOST 9625-2013 [24], which refers to GOST 13715-78 [21]. Specimens selection, their quantity, making and preparing for testing was done according to GOST 9620-94 [22]. The sprecimen's thickness is equal to the thickness of the BB h=19 mm, the specimen b=50 mm, and, the length l_1=15h=15·19=285 mm. When testing the specimens whose length l_1=15h, the spacing between supports l is taken equal to l=12h=12·19=228 mm (Fig. 7).

Test specimens for determination of shearing dry strength along glue line were made according to GOST 9624-93 [23]. Selection of models of their manufacturing, their fabrication and preparing for testing is done according to GOST 9620-94 [22]. The shape and dimensions of test specimens for determination of shearing strength along glue line should correspond to the 85×40×19 mm dimensions with the kerf of 5 mm (Fig. 7).

Fig. 7. Examples of front PCW-made blockboards for testing

To suit GOST 9625-2013 [24] for measuring static-bending strength across strips the following guidlines must be followed: in order to determine static bending strength across strips the laboratory test machine UMM-05 (GOST 7855-61) (Fig. 8)was used while the test machine PM-05 (GOST 28840-90) was used to determine shearing strength.

Fig. 8. Test specimen a facades blockboard with a coreboard made from PCW and face decks made from WFB at the moment of breakage

Static bending strength ($\boldsymbol{\sigma_u}$) in MPa was calculated by the formula:

$$\boldsymbol{\sigma_u=3P_{max}l/(2bh^2)} \tag{1}$$

The srtength along glue line $\boldsymbol{\tau_{ск}}$ is determined in MPa by rounding the result to 0.05 MPa by the

$$\boldsymbol{\tau_{ск}=P_{max}/(b_{ск}l_{ск})}\ , \tag{2}$$

where: $\boldsymbol{P_{max}}$ – maximum load, H; $\boldsymbol{l}$ – spacing between supports, mm; $\boldsymbol{b}$ – the width, mm; $\boldsymbol{h}$ – the specimen thickness, mm; $\boldsymbol{b_{ск},\ l_{ск}}$ – the width and the length of the shear area, mm.

Results of experimental studies. Complete factorial plan allows obtaining a linear dependence of the function of strength on the factors investiguted. For most part of wood working processes the representation like this would be inadequate. Therefore, other kinds of plan were used, that is plans by means of which one can obtain a mathematical description of objects in the form of polynom of the second order (quadratic model). At these plans, each factorxi varies at three levels, that is it takes one of the three values in every test: the lowest $X_{i\ min}$ the highest $X_{i\ man}$ and the mean $X_{i\ 0}$. At normalized values, these levels are denoted respectively ***-L, +L, 0***.

Generally, the regression model for ***k*** variable factors will read:

$$y = b_0 + \sum_{i=1}^{\kappa} b_i x_i + \sum_{i=1}^{\kappa} b_{ii} x_i^2 + \sum_{i,u=1}^{k} b_{iu} x_i x_u\ , \tag{3}$$

where: $\boldsymbol{b_o}$ – free term; $\boldsymbol{b_i}$ – linear regression coefficients, ***i=L,k;*** $\boldsymbol{b_{ii}}$ – quadratic regression coefficients; $\boldsymbol{b_{iu}}$ – pairwise coefficients, ***u=L,k (i≠u).***

Results and discussion on shape stability of front PCW-made blockboards.

As a result of the experimental data processing, a second-order regression equation was obtained which describes the dependence of the sag on the width of the structural elements, i.e. the width of PCW-made strips (solid wood) – B_{PCW} (x_1) and the thickness of face decks made from WFB – H_{WFB} (x_2).

Graphical representation of the obtained regression curves is shown in Fig. 9 and Fig. 10. The resulting regression equation in normalized values of variables takes the form:

$$y=0.137+0.016x_1-0.072x_2+0.006x_1^2+0.023x_2^2-0.003x_1x_2, \quad (4)$$

While in natural values of variables it can be written as:

$$S = 1.033 + 0.0005B_{PCW} - 0.293H_{WFB} + 0.00006B_{PCW}^2 + 0.023H_{WFB}^2 - 0.0003B_{PCW}H_{WFB} \quad (5)$$

where: B_{PCW} is the width of PCW-made (solid wood) strip of blockboard, in mm; H_{WFB} is the thickness of face decks made from WFB, in mm; S is the averaged deviation from flatness, that is the sag of blockboard, in mm.

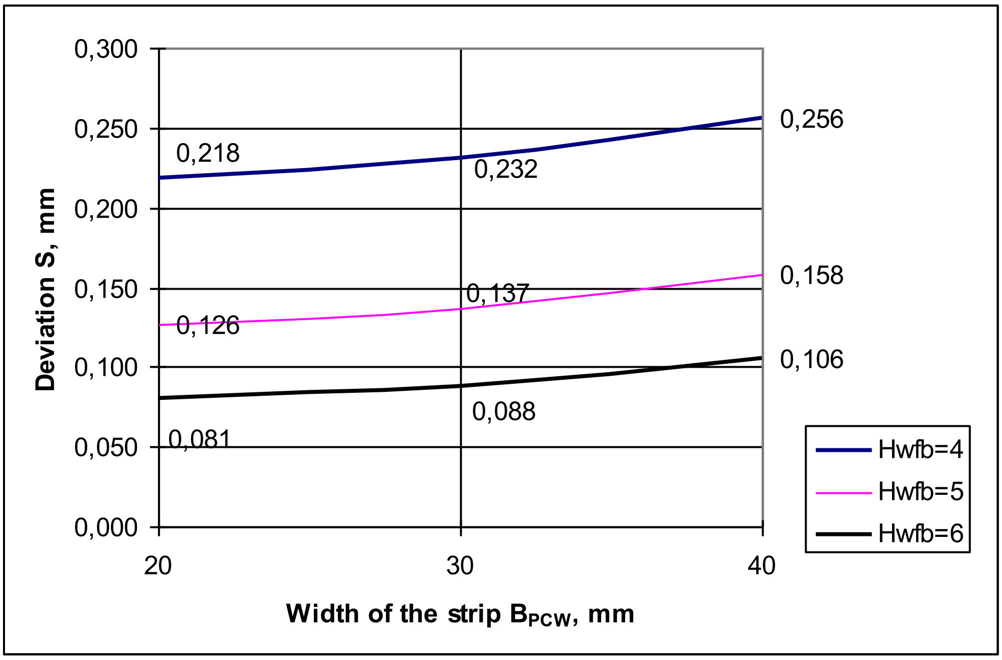

Fig. 9. Dependence of the averaged deviation S from flatness of the blockboards on the width of PCW-made strip (solid wood) – B_{PCW} (x_1).

The deviation from flatness (sag) for accuracy degree 12 for all the experimental specimens meets the requirements of the GOST 6449.3:1982 (Table 2).

Table. 2. Comparison of experimental and calculated values with the standardized values

No.	Input variables, mm			Objective (response) function, mm	
	natural values		flatness tolerance for block-boards size 440×440	experimental value Y_{exp}	calculated value Y_{calc}
	B_{PCW}	H_{WFB}	degree of accuracy 12		
1	20	4	0.3	0.219	0.218
2	40	4	0.3	0.255	0.256
3	20	6	0.3	0.082	0.081
4	40	6	0.3	0.105	0.106
5	20	5	0.3	0.124	0.126
6	40	5	0.3	0.160	0.158
7	30	4	0.3	0.232	0.232
8	30	6	0.3	0.088	0.88
9	30	5	0.3	0.133	0.137

As can be seen from Fig. 9, increasing the width of PCW-made strip (solid wood) leads to increased deviation S (sag). However, the dependence of the blockboard's sag on the thickness of face decks made from WFB is a reverse one (Fig. 10). It should be noted that the nature of the strip width effect on the average deviation S is nonlinear, although it is possible with a certain probability to suggest the presence of tendency for reverse (Fig. 9) and direct proportionality (Fig. 10).

The results of the experiments made it possible to optimize the width of strips using the gradient method, which revealed that the minimum deviation value S_{min} = 0.076 mm, taken in absolute value, can be obtained by establishing dimensional parameters for the width of the PCW-made strips of the blockboards as follows: B_{PCW} = 20 mm; thickness of face decks made from WFB – H_{WFB} = 6 mm (Fig. 11).

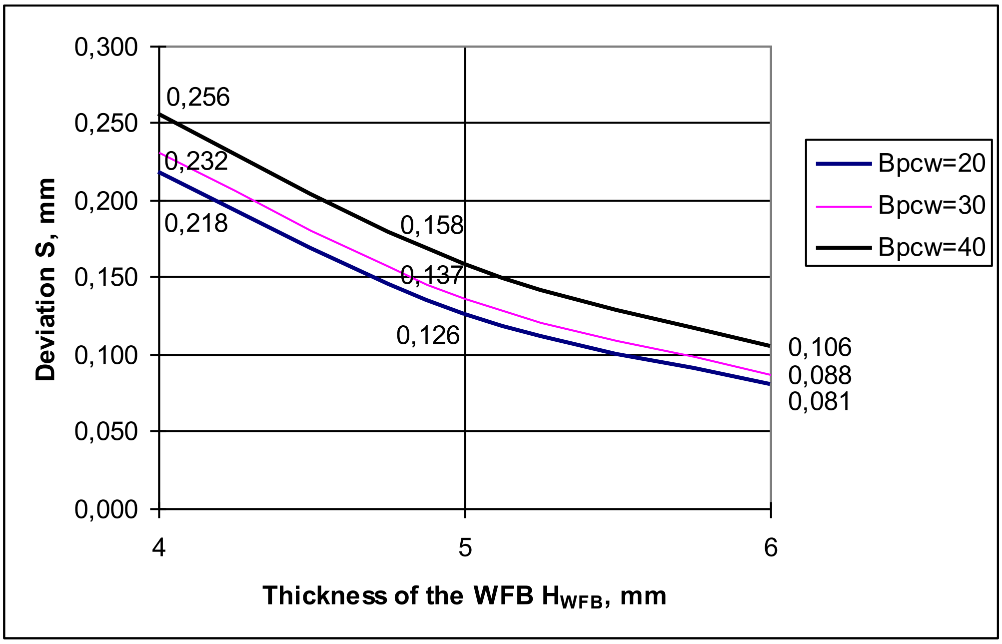

Fig. 10. Dependence of the averaged deviation S from flatness of the blockboards on the thickness of face decks made from WFB – H_{WFB} (x_2)

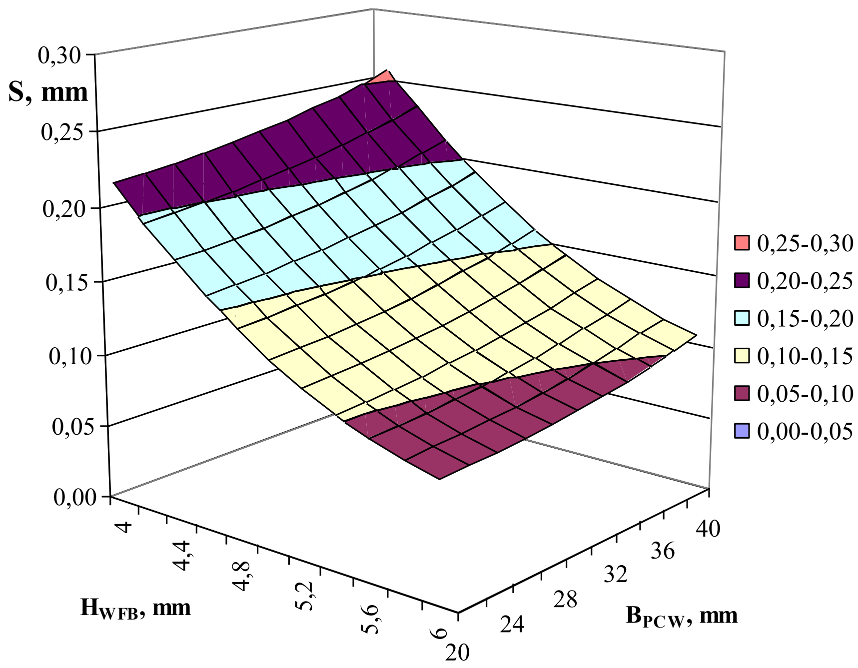

Fig. 11. Dependence of the averaged deviation S from flatness of the blockboards on the width of PCW-made and thickness of face decks made from WFB.

Results and discussion of static-bending strength across strips of front PCW-made blockboards. Having carried out statistical processing of experimenntal data we have the following regression equation:

$$y=22.978–1.73x_1–3.658x_2+0.004x_1^2+1.008x_2^2+0.017x_1x_2, \quad (6)$$

When analysing the regression equation, we can see that the factor $\boldsymbol{x_2}$, certainly, has the most influence on the output value of the function while factor's $\boldsymbol{x_1}$ influence is significantly less. Besides, output values to decrease up with an increase in $\boldsymbol{x_1}$ and $\boldsymbol{x_2}$ values. In order to determine equation coefficients in natural expression letus make use of factors coding formulas which we insert into the coded equation.

$$\boldsymbol{\sigma_u} = 84,044 – 0,26B_{PCW} – 13,8H_{WFB} + 0,00004B_{PCW}^2 + 1,008H_{WFB}^2 – 0,0017B_{PCW}H_{WFB} \quad (7)$$

The static-bending strength across strips σ_u of front PCW-made blockboards 19 mm thick for all the experimental specimens, except for No.4, meets the requirements of the GOST 13715-78 (Table 3).

Table. 3. Comparison of experimental and calculated values with the standardized values

No.	Input variables, mm			Objective (response) function, mm	
	natural values		static-bending strength across strips σ_u, MPa	experimental value Y_{exp}	calculated value Y_{calc}
	B_{PCW}	H_{WFB}	blockboards 19 mm thick		
1	20	4	20	29.048	29.395
2	40	4	20	25.926	25.901
3	20	6	20	22.020	22.046
4	40	6	20	18.966	18.619
5	20	5	20	25.084	24.712
6	40	5	20	20.880	21.252
7	30	4	20	27.966	27.644
8	30	6	20	20.006	20.328
9	30	5	20	22.755	22.978

Graphical representation of the obtained regression curves is shown in Fig. 12 and Fig. 13.

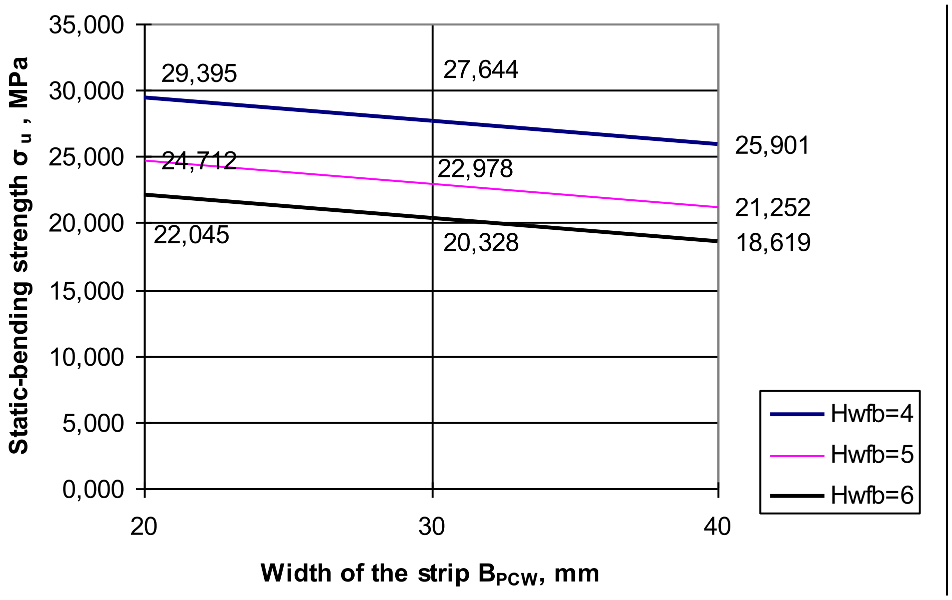

Fig. 12. Dependence of the static-bending strength across strips σ_u of the facades blockboards on the width of PCW-made strip (solid wood) – B_{PCW} (x_1).

As can be seen from Fig. 12, increasing the width of PCW-made strip (solid wood) leads to decrease static-bending strength across strips σ_u. The dependence of the blockboard's sag on the thickness of face decks made from WFB is similar (Fig. 13).

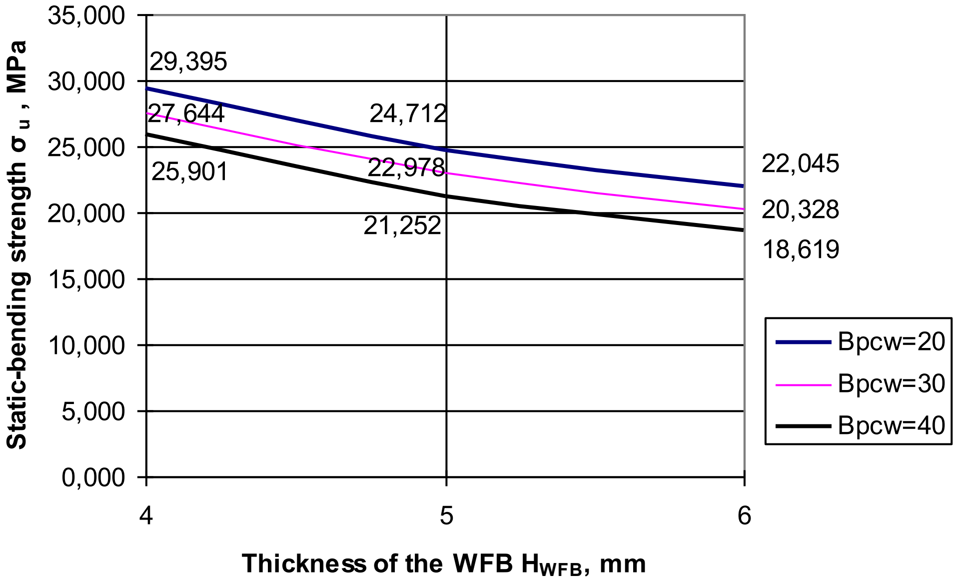

Fig. 13. Dependence of the static-bending strength across strips σ_u of the facades blockboards on the thickness of face decks made from WFB – H_{WFB} (x_2).

Thus, the static-bending strength of BB is influencer the most by the thickness of face decks made from WFB while strip width being of little influence.

The results of the experiments made it possible to optimize the width of strips using the gradient method, which revealed that the maximum deviation value static-bending strength across strips σ_u = 29,395 MPa, taken in absolute value, can be obtained establishing dimensional parameters for the width of the PCW-made strips of the blockboards as follows: B_{PCW} = 20 mm; thickness of face decks made from WFB H_{WFB} = 4 mm (Fig. 14).

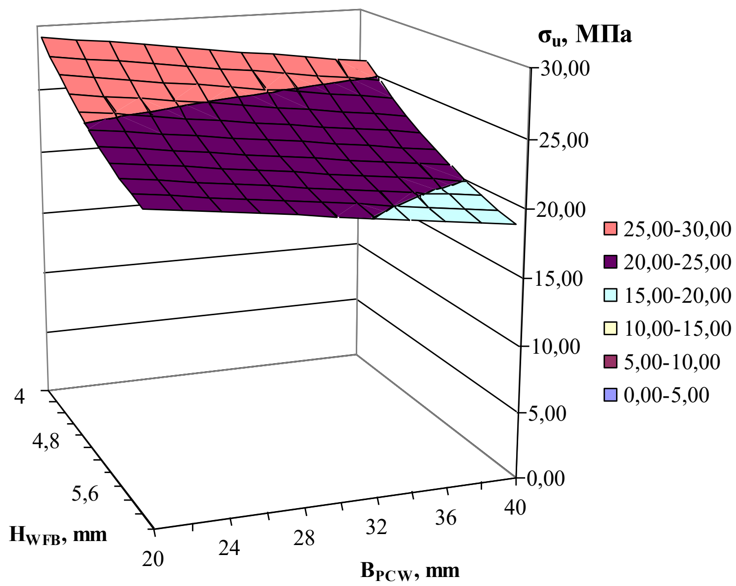

Fig. 14. Dependence of the static-bending strength across strips σ_u of the facades blockboards on the width of PCW-made strips and thickness of face decks made from WFB

Results and discussion of shearing dry strength along the glue line of front PCW-made blockboards. Having carried out statistical processing of experimenntal data we have the following regression equation:

$$y=1.469+0.12x_1-0.08x_2-0.007x_1^2-0.139x_2^2+0.0005x_1x_2, \quad (8)$$

In order to determine equation coefficients in natural expression letus make use of factors coding formulas which we insert into the coded equation.

$$\tau_{ск} = 1,116 + 0,05375B_{PCW} + 1,3085H_{WFB} - 0,00007B_{PCW}{}^2 - 0,139H_{WFB}{}^2 - 0,00005B_{PCW}H_{WFB} \quad (9)$$

When analysing the regression equation, we can see that the factor $H_{WFB,}$ certainly, has the most influence on the output value of the function while factor's B_{PCW} influence is significantly less. Besides, output values grow up with an increase in B_{PCW} values, output values teng to decrease as factor's H_{WFB} value increases. Graphical representation of the obtained regression curves is shown in Fig. 15 and Fig. 16.

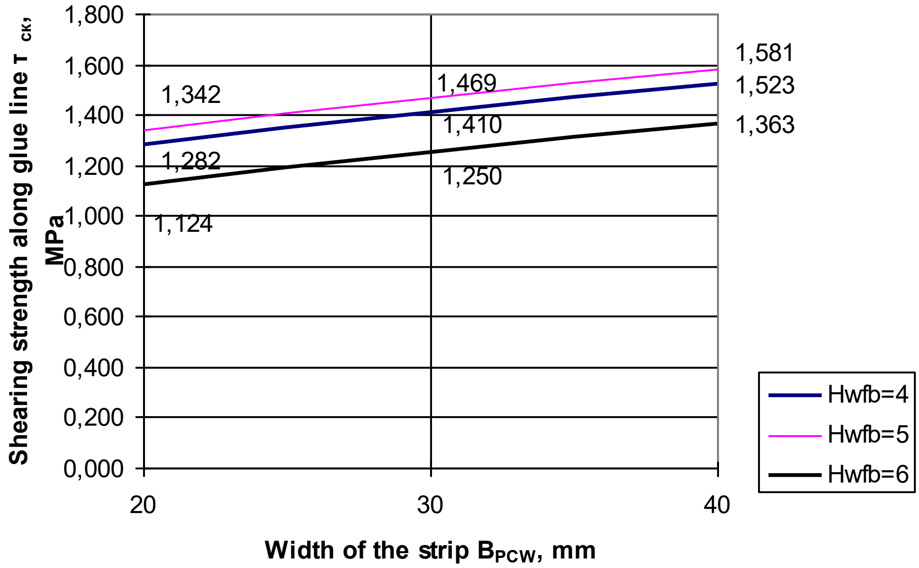

Fig. 15. Dependence of the shearing dry strength along the glue line $\tau_{ск}$ of the facades blockboards on the width of PCW-made strip (solid wood) – B_{PCW} (x_1)

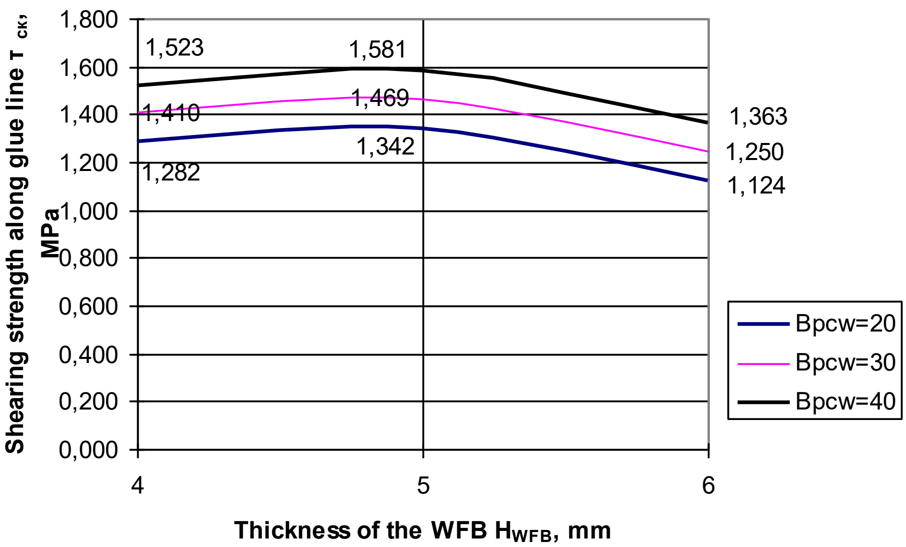

Fig. 16. Dependence of the shearing dry strength along the glue line $\tau_{ск}$ of the facades blockboards on the thickness of face decks made from WFB – H_{WFB} (x_2)

The ***shearing dry strength along the glue line*** $\tau_{ск}$ of front PCW-made blockboards 19 mm thick for all the experimental specimens meets the requirements of the GOST 13715-78 (Table 4).

Table. 4. Comparison of experimental and calculated values with the standardized values

No.	Input variables, mm			Objective (response) function, mm	
	natural values		shearing dry strength $\tau_{ск}$, MPa	experimental value Y_{exp}	calculated value Y_{calc}
	B_{PCW}	H_{WFB}	blockboards 19 mm thick		
1	20	4	1	1.303	1.282
2	40	4	1	1.507	1.523
3	20	6	1	1.140	1.124
4	40	6	1	1.342	1.363
5	20	5	1	1.305	1.342
6	40	5	1	1.618	1.581
7	30	4	1	1.405	1.410
8	30	6	1	1.255	1.250
9	30	5	1	1.457	1.469

The results of the experiments made it possible to optimize the width of strips using the gradient method, which revealed that the maximum deviation value ***shearing dry strength along the glue line*** $\tau_{ск}$ = 1.581 MPa, taken in absolute value, can be obtained establishing dimensional parameters for the width of the PCW-made strips of the blockboards as follows: B_{PCW} = 40 mm; thickness of face decks made from WFB H_{WFB} = 5 mm (Fig. 17).

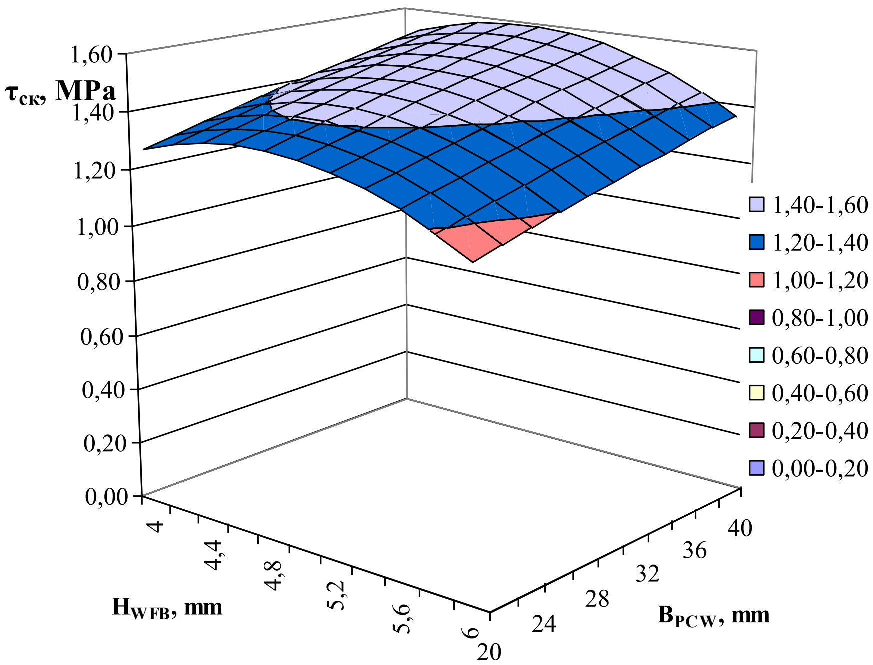

Fig. 17. Dependence of the shearing dry strength along the glue line $\tau_{ск}$ ***of the facades blockboards on the width of PCW-made strips and thickness of face decks made from WFB***

Conclusions:

1. It has been proved that PCW is a suitable secondary raw material resource for manufacturing front blockboards because this wood has a low moisture content (W = 8±3%) and stable internal stresses, which has a positive effect on shape stability – the stress-strain state of the blockboards' construction.

2. PCW-made blockboards' constructions have been proposed which are suitable for the manufacture of front furniture products.

3. Physical-and-mechanical properties of front PCW-made blockboards have rather a high scattered field, nevertheless, they are subordinated to the law of normal distribution, which was confirmed by Pirson's criterion when analyzing the sample of one hundred speciment tested for static bending strength across strips, shearing dry strength along the glue line, shape stability.

4. Physical-mechanical parameters of all front PCW-made blockboards 19 mm in thickness, regardless of their design (thickness of the wood fiberboard) meet GOST 13715-78 requirements.

5. The highest level of physical-and-mechanical properties in front PCW-made blockboards is found in the following conditions: B_{PCW} = 20 mm; H_{WFB} = 6 mm – shape stability will be 0.082 mm; B_{PCW} = 20 mm; H_{WFB} = 4 mm – static-bending strength across strips – 29.395 MPa; B_{PCW} = 40 mm; H_{WFB} = 5 mm – shearing dry strength along the glue line – 1.581 MPa.

6. The patterns of the strip width and the influence of thickness of the woodfiberboard upon shape stability, static-bending strength across strips and shearing dry strength along the glue line of front PCW-made blockboards have been established.

7. The obtained regression models are adequate and, therefore, can be used to describe the object of study.

8. It is shown that in order to ensure high shape stability of PCW-made blockboards, we must use wooden strips of predominantly radial cut with further facing with woodfiberboard 6 mm thick.

Recommendations for use of PCW-made blockboards:

1. To obtain shape stability and maximam static bending strength of BB across strips it is recommended that the width of the strips used for the core of PCW-made blockboard should not exceed its 2.5 – fold thickness.

2. To ensure shape stability of PCW-made blockboards which operate under conditions of varying humidity, it is desirable to apply the 1:3 aspect ratio in the cross-section of strips, while annual rings angle in the ends of the strips shall not be less than 45°.

3. To obtain front PCW-made blockboards ,whose surfaces meet the requirements of the depth of milling, GOST 13715-78, it is enough to cover the core with woodfiberboard 5-6 mm thick.

Practical advice and guidelines. Recommendations for design and technologies of front PCW-made blockboards 19 mm thick:

- strips moisture content – 8 ± 2%;
- for strips made from solid wood: width = 2.5 thickness,
- (thickness 7 (9), width – 17.5 (22.5) mm);
- strips arrangement – radial or at an angle of 45°;
- facing – woodfiberboard 5-6 mm thick;

- glue spread for the core – 200-250 g/m^2; glue spread for a blockboard – 150-200 g/m^2;
- clamp temperature for the core –85-90 °C; press temperature for the BB – 115-125 °C;
- press time for the core – 30-40 min; press time for the blockboards – 4-6 min;
- pressure for the core – 0.5-1.0 MPa; pressure for the blockboards – 1.2-1.3 MPa.

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Дослідження фізико-механічних характеристик фасадних столярних плит із вживаної деревини

Обґрунтовано доцільність використання вживаної деревини (ВЖД) для матеріального виробництва. Запропоновано переробляти ВЖД на столярну плиту (СП). Запропоновано нові конструкції СП із ВЖД, які є придатними для виготовлення фасадів меблевих виробів. Експериментально підтверджено, що фізико-механічні властивості фасадних СП із ВЖД відповідають вимогам стандартів. Одержано закономірності впливу ширини рейок та товщини деревноволокнистої плити (ДВП) на формостійкість, на міцність при статичному згині впоперек рейок та на міцність при сколюванні по клейовому шарі в сухому стані фасадних СП із ВЖД. Отримано адекватні регресійні моделі, які можуть бути використані для опису об’єкта дослідження. Запропоновано практичні рекомендації щодо виготовлення та використання фасадних СП із ВЖД для меблевого виробництва.

Висновки:

1. Обґрунтовано, що ВЖД є придатним вторинним ресурсом для виготовлення фасадних СП, оскільки дана деревина має низьку вологість (W=8±3 %) та стабільні внутрішні напруження, що позитивно впливає на формостійкість – напружено-деформований стан конструкції СП.

2. Запропоновано нові конструкції СП із ВЖД, придатних для виготовлення фасадів меблевих виробів.

3. Фізико-механічні властивості СП із ВЖД мають досить високе поле розсіювання, тим не менше вони піддаються закону нормального розподілу, що було підтверджено критерієм Пірсона при аналізі вибірки із ста взірців, випробуваних на міцність при статичному згині впоперек рейок, на міцність при сколюванні по клейовому шву, формостійкість.

4. Фізико-механічні параметри всіх фасадних СП із ВЖД товщиною 19 мм не залежно від їх конструкції (товщини личківки) задовольняють вимоги стандартів [20, 21].

5. Найвищими фізико-механічними параметрами характеризується фасадні СП із ВЖД за таких умов: $B_{ВЖД}$ = 20 мм; $H_{ДВП}$ = 6 мм – формостійкість буде становити 0,082 мм; $B_{ВЖД}$ = 20 мм; $H_{ДВП}$ = 4 мм – міцність на статичний згин впоперек рейок – 29,395 МПа; $B_{ВЖД}$ = 40 мм; $H_{ДВП}$ = 5 мм – міцність на сколювання по клейовому шарі в сухому стані – 1,581 МПа.

6. Одержано закономірності впливу ширини рейок та товщини ДВП на формостійкість, на міцність на статичний згин впоперек рейок та на міцність на сколювання по клейовому шарі в сухому стані фасадних СП із ВЖД.

7. Отримані регресійні моделі є адекватними, а отже можуть бути використані для опису об’єкта дослідження.

8. Обґрунтовано, що для забезпечення високої формостійкості фасадних СП із ВЖД необхідно використовувати дерев’яні рейки переважно радіального перерізу та личкувати ДВП товщиною 6 мм.

Практичні рекомендації:

1. Для досягнення формостійкості та максимальної міцності СП на статичний згин впоперек рейок, рекомендується ширину рейки СП із ВЖД приймати не більше 2,5 її товщини.

2. Для отримання фасадних СП із ВЖД, поверхня яких відповідала вимогам глибини фрезерування, достатньо личкувати ДВП товщиною 5-6 мм.

3. Для забезпечення формостійкості СП із ВЖД, які експлуатуються в умовах змінної вологості, бажано застосовувати співвідношення сторін у поперечному перерізі рейок 1:3, а кут нахилу річних шарів в торці рейок повинен бути не менше 45°.

Рекомендації до конструкцій і технологій фасадних СП із ВЖД товщиною 19 мм:

- вологість рейок – 8±2 %;
- для рейок з масиву : ширина = 2,5 товщини
  товщина 7 (9), ширина – 17,5 (22,5) мм;
- розташування рейок – радіальне, або під кутом 45°;
- личкувати – ДВП товщиною 5-6 мм;
- витрата клею для щита – 200-250 г/м^2;
- витрата клею для СП – 150-200 г/м^2;
- температура вайми для щита – 85-90 °C;
- температура преса для СП – 115-125 °C;
- час витримки під тиском для щита – 30-40 хв;
- час витримки під тиском для СП – 4-6 хв;
- тиск для щита – 0,5-1,0 МПа; для СП – 1,2-1,3 МПа.

Ключові слова: деревина, вживана деревина (ВЖД), столярна плита (СП), деревноволокниста плита (ДВП), перероблення, фасадні поверхні, конструкції СП, технології, формостійкість, міцність.