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STUDIES OF COMPONENT INTERCONNECTION IN A PLYWOOD STRUCTURE WITH INTERNAL LAYERS OF VENEER CHIPS

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ABSTRACT

The impact of the assembly diagrams of plywood package with internal layers of veneer chips on the performance of component interconnection, i.e. surface soundness and interfacial interaction in response to equal cleavage and chipping is presented in the paper. Rational design of plywood package assembly providing the required physical and mechanical properties is described as well. The fact that cohesive destruction of wood particles occurs regardless of the assembly scheme when veneer layers are torn off and when plywood is cut along the boundary layers of plywood with internal layers on the basis of wood particles was found. Soundness of the joint at the interface between the layers of veneer and wood particles is due to the presence of an adhesive layer with an increased glue content. The maximum pull-off strength is observed in plywood samples with a central veneer layer. Therefore its use in critical structures is recommended. This type of plywood can be used effectively as a structural material in various fields.

Keywords: plywood, veneer sheets, veneer chips, bond quality, surface soundness, interfacial interaction

INTRODUCTION

The refuse wood is an inevitable part of the plywood production. Inclusion of wood processing waste into the production of wood composite materials helps reduce the cost of the end products and utilize them more effectively (STRELKOVA & NOVIKOVA 1993; UGRUMOV & SMIRNOV 2006).

It is highly recommended to use glued wood particles of milled refuse, accompanying plywood production, for the manufacture of the inner layers of plywood. The basis of the strength of such a material is a peeled veneer, and a composition based on wood particles, mixed with a synthetic binder, serves as a filler (UGRUMOV *et al*. 2007; MALISHEVA 2013). Plywood with inner filling of veneer chips can effectively dispose the generated refuse wood, reduce production costs, and expand the range of products, while maintaining their quality and competitiveness, which is relevant for the woodworking industry.

It is important to predict strength properties of the plywood, and the degree of interfacial interaction between the veneer sheets and an inner filling, because it allows to adjust the assembly diagram and the composition depending upon the desired properties and fields of application.

Any system of adhesive (liquid) - the substrate (solid) can be characterized by the adhesion and fracture mode (disbond mode among the components). Knowing the weaknesses of the material, can make it easier to improve its efficiency and durability (BERLIN 1990; UGRUMOV & SVESHNIKOV 2010). The interfacial interaction in plywood with internal layers of veneer chips can be better observed at phase boundaries: liquid (binder) - solid (wood particles); liquid (binder) - solid (peeled veneer).

We will consider as the structure of the plywood package with internal layers of veneer chips the number of layers of veneer of a certain thickness, alternating with the internal layers of the glued wood particles procured from milled refuse of plywood production. The paper discusses the efficient structures of plywood package filled with wood particles and their physical and mechanical properties.

Another issue is the estimation of the value of the surface soundness and interfacial interactions at phase boundaries (layers of peeled veneer sheets and veneer chips) in a plywood structure.

MATERIALS AND METHODS

The objective of the paper is to estimate the value of the surface soundness and interfacial interactions at the boundaries of peeled veneer sheets and veneer chips composition depending on the assembly diagram of the plywood package and recommend effective schemes for assembling a plywood package.

Issues to be solved are as follows: to estimate the interfacial interaction and surface soundness of veneer chips depending on the package structure, and to recommend the efficient structure of plywood package.

Plywood samples of the format 400x400 mm were produced according to various schemes of assembly in a hydraulic laboratory press P100-400. During the experimental assembly the urea-formaldehyde resin adhesive was applied; birch peeled veneer with 1.5 mm thickness was used in the outer and central layers, and specially sorted birch chips were used in the internal filling (the chips passed through a 10 mm-hole diameter sieve and remained on a 5 mm-hole diameter sieve); the production process was carried out at following constant factors:

- plywood board thickness, mm – 16;
- temperature of press - 130˚C;
- specific pressing pressure - 2 MPa;
- exposure time under a pressure - 16 min.

The mass of wood particles in the formation of internal layers was calculated in such a way that, after pressing, the density of plywood samples was 700 kg/m^3.

The production of experimental samples was carried out according to a one-stage scheme. In accordance with the assembly scheme, samples consisting of the necessary number of layers of veneer and tarred wood particles were formed, further they were pressed in a cold press to increase transportability, and then pressed in a hot press with 16 mm thick stoppers.

Ready-assembled plywood samples were conditioned for 1 day, and then were cut to the appropriate samples for testing.

The method of estimating the value of the surface soundness in the cleavage of peeled veneer sheets according to GOST (State Standards of Russia) 27325 and the method of determining the strength of chipping in accordance with GOST 9624 were basic in the research.

The summary of the method of evaluating the surface soundness in the cleavage layer is a separation of an area of face layer (sheets of peeled veneer) from the base coat (the inner layers of the wood-adhesive composition) in a direction perpendicular to the latter, depending on the assembly design of the plywood package retaining the fracture load.

50 × 50 mm plywood samples were used to determine surface soundness. The surface of the birch cylinder was smoothly covered with epoxy adhesive. Further, the cylinder was glued perpendicular to the horizontal plane on the center of the sample, and exposed it for 24 hours under normal conditions. Upon exposure, the surface of the coatingwas drilled to the base coat around the cylinder, allowing the emergence of the drilling footprint on the inner layer of wood-adhesive composition. The test piece of plywood with internal layers of wood-adhesive composition is shown in Fig. 1.

Fig. 1 The image of the sample to determine the surface soundness.

The tearing machine P-5 was used for the tests. The test samples were mounted in a test fixture. The test device was attached to the upper jaw of the machine through a cylinder according to the scheme shown in Fig. 2.

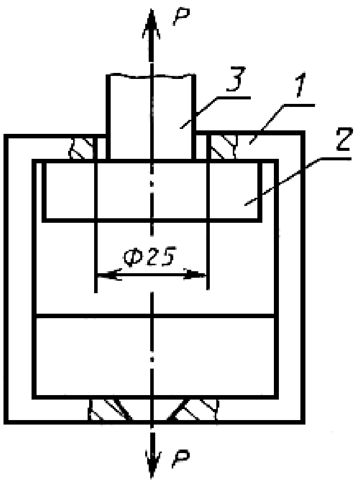


Fig. 2 Scheme of the sample mounting in the tearing machine: 1 - sample capture; 2 - sample; 3 - birch cylinder.

The tests were performed for the outer and central peeled veneer sheets to determine the effect of the structure of the assembly package on the value of the adhesive strength and interfacial interaction.

Figure 3 shows the cylinder installation diagrams when testing the surface soundness of outer and central peeled veneer sheets in the package, depending on the design of the assembly.

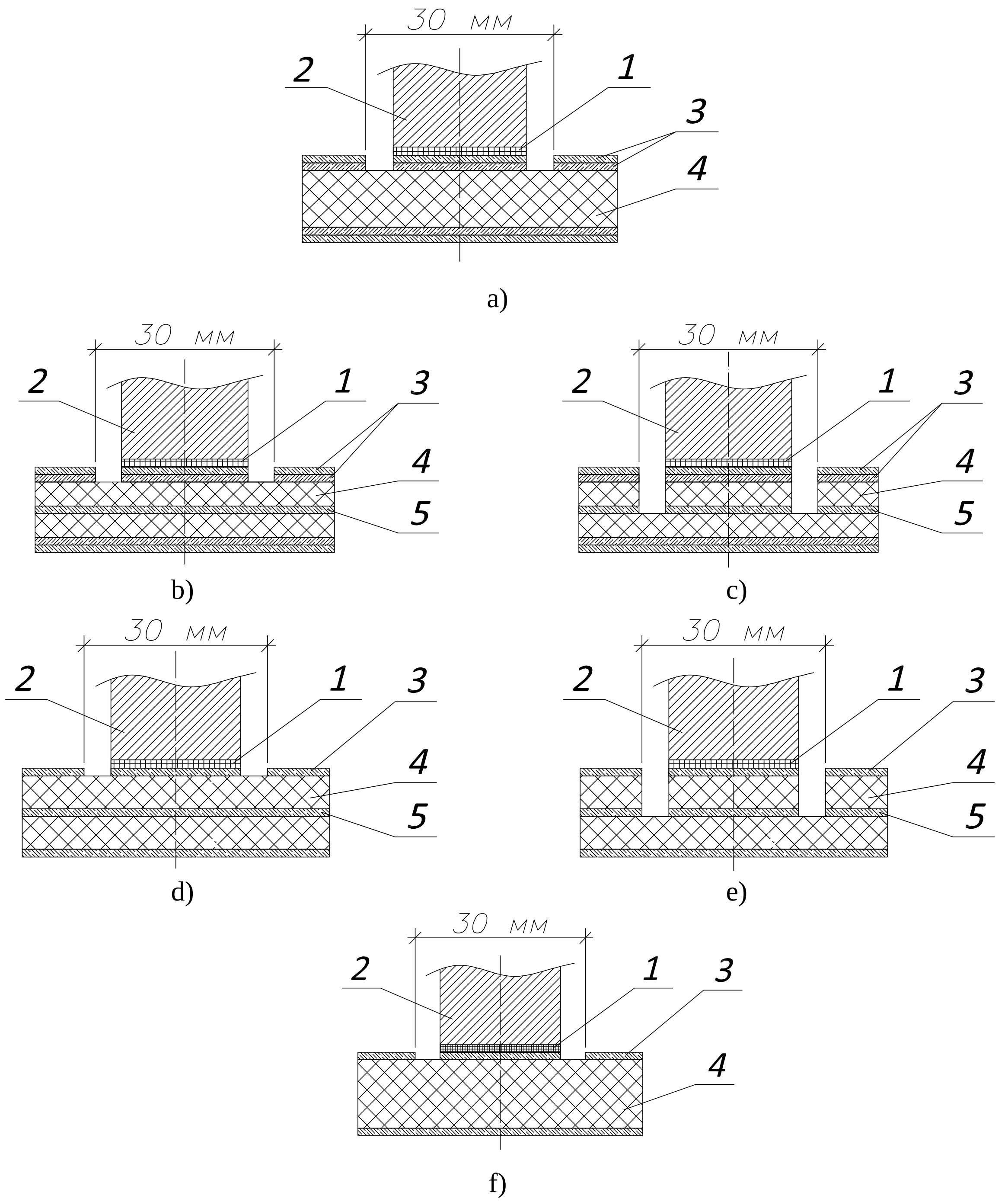
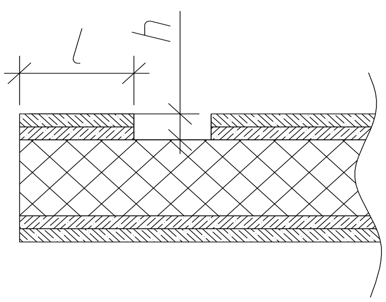
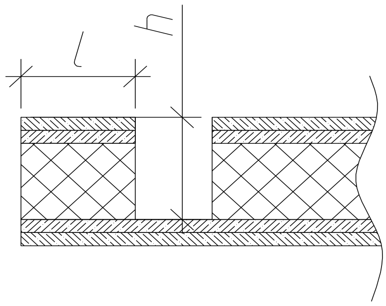


Fig. 3 Cylinder installation diagrams during the test: a) assembly diagram No 1 (outer veneer sheets); b) assembly diagram No 2 (outer veneer sheets); c) assembly diagram No 2 (central veneer sheets); d) assembly diagram No 3 (outer veneer sheets); e) assembly diagram No 3 (central veneer sheets); f) assembly diagram No 4 (outer veneer sheets). 1 - a layer of epoxy glue; 2 - birch cylinder; 3 - outer veneer sheets; 4 – the central veneer sheet.

The ultimate split strength and fracture pattern were measured by the results of the tests.

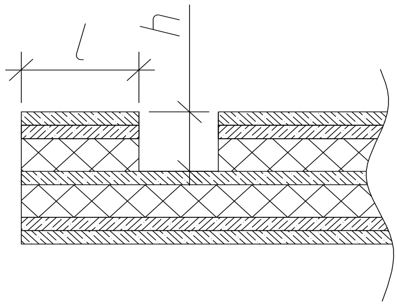
Samples shown in Figure 4 were manufactured to determine the strength of chipping along the phase boundaries.

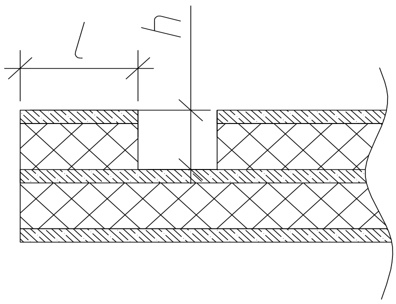




a)

b)





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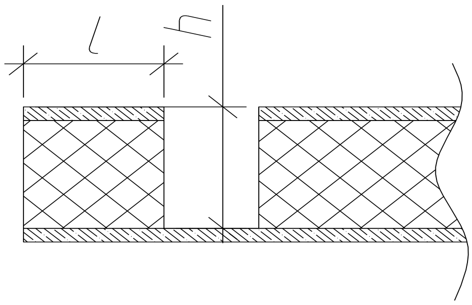

e)

Fig. 4 The form of the samples to determine the chipping strength: a) assembly diagram No1a (upper veneer sheets); b) assembly diagram No 1b (bottom veneer sheets); c) assembly diagram No 2; d) assembly diagram No 3; e) assembly diagram No 4.

The length of the sample was 85 mm, and the thickness - 16 mm. The cutting width was determined depending on the thickness of the saw cut and ranged from 8 to 15 mm to ensure whole capture by the test device. The cutting depth *h* was determined according to the package structure. The length of the chipping plane 1 was (12.5 ± 0.5) mm.

The test machine P-5, equipped with wedge grips, was used to determine wood ultimate split strength at the phase boundary. The fracture load was recorded for each sample, further the ultimate split strength and the nature of the fractures were determined.

RESULTS

In most cases, the fractures can be classified as follows: adhesive (adhesive is entirely separated from the substrate), cohesion (failure occurs on the adhesive layer or on the base coat), and mixed (adhesive-cohesive, in which there is a partial separation of the adhesive (adhesive layer) from the substrate (base coat) or partial fracture of the substrate and the partial fracture of the adhesive).

The adhesion strength for the main plywood assembly diagrams has been determined experimentally in response to equal cleavage of outer and central veneer sheets.

Figure 5 shows the dominant character of the samples fracture upon the completion of the cleavage test on veneer sheets.

Fig. 5 . The typical plywood sample fracture in response to cleavage.

Table 1 represents the results of experimental studies to determine the adhesive strength of plywood with internal layers of wood-adhesive composition in response to cleavage of veneer sheets.

Tab. 1 Soundness of plywood in response to tearing off veneer sheets from internal layers.

No of the assembly diagram	Soundness of plywood when tearing off veneer sheets from internal layers, MPa						Type of fracture of the sample during the test	
	outer veneer sheets			central veneer sheets				
	Average value	Standard deviation	Coefficient of variation, %	Average value	Standard deviation	Coefficient of variation, %	outer ply	Central ply sheet
1	1.59	0.032	1.87	-	-	-	cohesively on the inner layer of veneer chips	-
2	1.63	0.051	3.35	1.25	0.033	2.40	mixed type (veneer / wood particles)	mixed type (veneer / wood particles)
3	1.67	0.050	3.23	1.23	0.015	0.81	cohesively on the inner layer of veneer chips	mixed type (veneer / wood particles)
4	1.65	0.112	6.82	-	-	-	mixed type (veneer / wood particles)	-

The obtained data show that when veneer sheets are removed, a cohesive destruction along veneer chips is observed, or a mixed character of destruction, that is, simultaneous destruction of veneer and wood particles, which indicates a high interfacial bond strength.

The nature of the interfacial interaction of liquid (binder) with a solid body (wood particles and veneer) at the boundary of their interaction, depending on the plywood assembly diagram, was determined by cleaving along the boundary of the contact of the outer veneer sheet and the inner layer of veneer chips, as well as the inner layer of veneer chips and the central veneer sheet.

For example, Figure 6 shows some typical samples at chipping fractures depending on the package structure.

Table 2 represents the results of experimental studies to determine the strength of plywood with internal layers of veneer chips in response to chipping.


a)

b)

c)

Fig. 6 The typical chipping fractures of the samples: a) assembly diagram No 1a; b) assembly diagram No 3; c) assembly digram No 4.

Tab. 2 The strength of plywood in response to chipping on the adhesive layer.

No of the assembly diagram	Chipping strength in layers, MPa			The main type of the fracture of the samples during the test
	Average value	Standard deviation	Coefficient of variation	
1a	3.05	0.331	10.86	Cohesively on the veneer chips
1b	3.1	0.192	6.20	Mixed on glue line between the layers of veneer with tear-outs of wood fibers from the surface of the veneer
2	4.21	0.162	3.86	Cohesively the veneer chips
3	4.12	0.172	4.18	Cohesively on the veneer chips
4	3.15	0.158	5.02	Cohesively on the veneer chips

Thus, mainly cohesive on veneer chips or mixed nature of fracture was observed, which indicates a high interfacial strength of bonding.

DISCUSSION

We can mainly observe cohesive fracture on the veneer chips, regardless of the assembly diagram, in the process of the adhesive cleaving of veneer layers and chipping at the boundary layers of plywood with internal layers of venner chips. High adhesion strength at the phase interface (veneer layers and veneer chips) can be explained by the presence of an adhesive layer with a high content of glue, which contacts with pitched veneer sheet and glued wood particles.

Slight differences in the values of surface soundness at the phase boundaries, depending on their location, can be explained by the difference in the degree of cure of the binder along the cut of plywood - during the pressing the temperature of the central layers is less than of the outer ones, therefore, the completeness of binder cure in the inner layers is smaller than in the outer layers.

The maximum split strength was observed in the samples from the plywood with assembly diagrams No 2, and No 3, with the inner veneer layer, so these were recommended for the use in critical structures. The assembly diagrams No 1, and No 4 are regarded as simple from the perspective of the process of package formation.

The obtained results of the estimation of the physical and mechanical properties of plywood with internal layers of venner chips exceed the properties of analog materials. Thus, the obtained strength in the separation of veneer sheets from internal layers of wood chips, ranging from 1.23 to 1.67 MPa, depending on the assembly scheme, significantly exceeds the standardized and statistical values for analogue materials – chipboards and oriented stand boards (OSB) [8], and the strength at shearing along the layers, ranging from 3.05 to 4.21 MPa, exceeds the normalized and statistical values for general-purpose plywood [9], which indicates a high bond strength and a high reliability prediction of the material.

CONCLUSION

High level of surface soundness in response to cleavage of veneer sheets and deep interfacial interactions at the phase boundaries between layers of veneer and layers of wood-adhesive composition let us conclude that plywood with internal layers of veneer chips is reliable and possesses good capacities, and that it can be effectively used as a structural material in various fields.

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