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Results of the Comparison of the Strength of Adhesive Joints in Wooden Elements Made from Modified Materials

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Abstract: The production of glued structures from modified wood materials is a promising direction. The strength of the adhesive joint depends on various factors, such as the type of wood materials, the type of glue, the humidity of the material, the gluing mode, etc. The article provides the results and analysis of the strength of the adhesive joint from various factors.

Keywords: Modification, wood materials, complex chemical compositions. adhesive joint, adhesive joint strength, type of materials, type of glue, material humidity, glue composition, gluing mode.

Introduction

The production of elements and structures used under various complex operating conditions with modified wood materials is currently one of the most promising areas. Due to their high resistance to different aggressive environments, the physical and mechanical properties of such materials indicate that they offer several advantages over conventional wood materials [3]. Given the growing use of modified wooden materials in recent years, the analysis of their less-studied properties has become an important issue. In particular, this concerns the improvement and refinement of bonding technologies, the introduction of new methods tailored to various operational conditions, and the study of the strength of bonded materials [1]. It is known that modified materials possess characteristics of both natural wood and plastics. As such, the comprehensive study of these properties requires the use of various types of adhesives that can cure under both cold and hot conditions, unlike those used with regular wooden materials. Since modified wood exhibits higher rigidity and strength compared to natural materials, high-plasticity adhesives are used in the bonding process. The strength of adhesive joints depends on several factors: the pressure applied to the surfaces, the smoothness of the surfaces, the viscosity of the adhesive, and the extent to which the materials can withstand mechanical stress. As these parameters are interrelated in such bonding processes, it is advisable to analyze their effects on strength individually [7]. For wooden structures operating in harsh environments, protecting them from moisture and other aggressive impacts, as well as analyzing their underexplored properties, is essential—particularly in order to improve mechanical characteristics, refine bonding technologies, and develop methods suited to various operational conditions [5]. Urea-formaldehyde (KB-3) and phenol-formaldehyde (FR-12) adhesives were used for bonding wood materials modified with furan polymers. Polished specimens made from white birch were used for bonding under a pressure of 0.8 MPa for 1 hour with the application of furan-based compositions. The density of the polished samples was 0.73 g/cm³ with a polymer content of 45%. Before bonding, the surfaces of the samples were leveled using a specialized tool and fine-grit sandpaper, and then cleaned accordingly. The samples were found to have a moisture content of 5–6%. Adhesive was applied using a single-sided method. The curing temperature was 100–110°C; adhesive consumption ranged from 150 to 300 g/m²; bonding pressure was between 0.4 and 1.2 MPa; and the pressing time was between 20 and 40 minutes. During the strength testing of experimental samples, the specimens were joined in three different configurations:

Regular pine and birch boards;

Modified pine and birch boards; Modified pine and birch boards bonded with KB-3 and FR-12 adhesives under both cold and hot curing conditions. The effect of adhesive consumption on the bonding strength of birch-based samples is shown in Figure 1. According to the results of the experiment with modified materials, the optimal adhesive consumption for bonding was determined to be 270–300 g/m², which is 40–50 g/m² more than the amount used for bonding natural materials. The recommended pressure was 0.6–1.0 MPa, which is 0.4 MPa higher than that required for bonding natural wood. To study the influence of bonding pressure on the performance of modified materials under cold and hot conditions, pine and birch samples were tested using KB-3 and FR-12 adhesives. The results are summarized in Table 1.

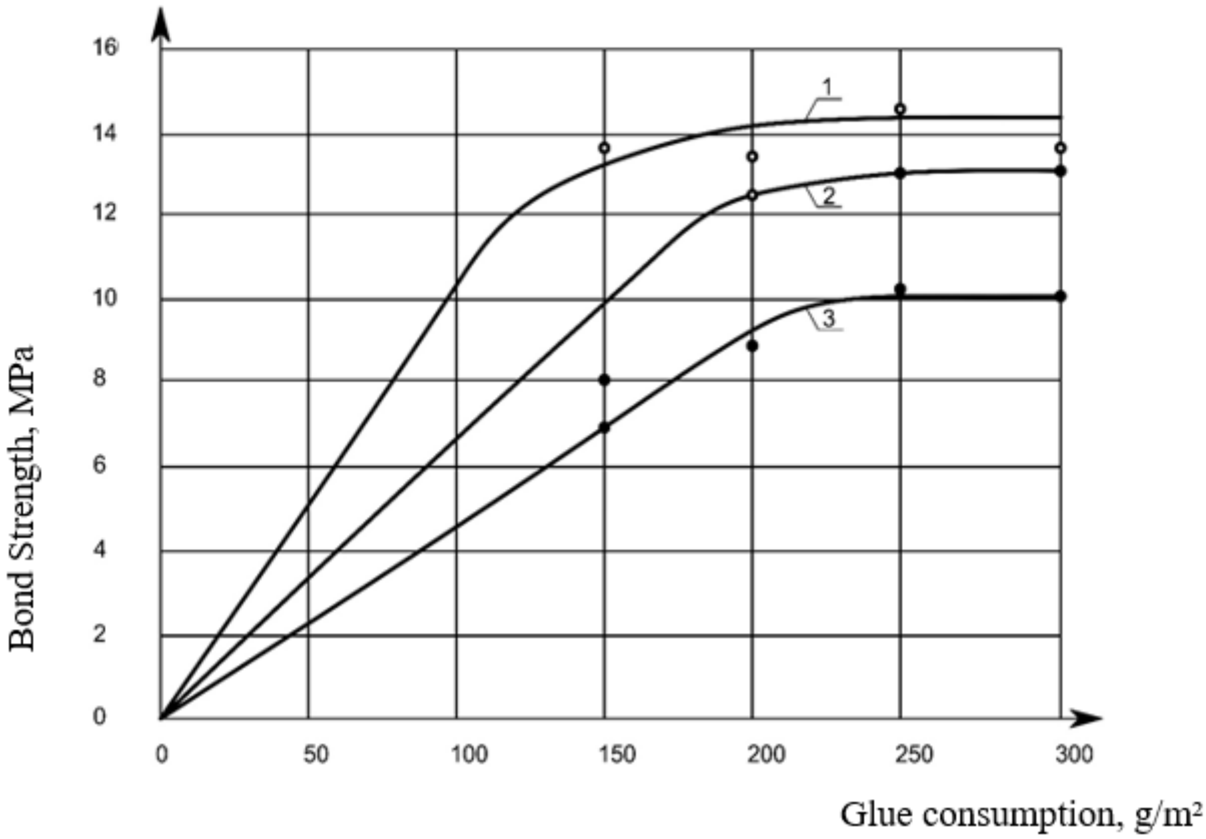

Figure 1. The effect of adhesive consumption on strength:
1 – regular birch boards glued together; 2 – modified birch boards; 3 – modified birch boards glued together.

During cold bonding, 25% Petroff contact was used as a hardener for the KB-3 type adhesive, and 13% paraform was used for the FR-12 type adhesive. For cold bonding, the cross-sectional surfaces of the samples were not cleaned. The average glue consumption was 250–300 g/m². The pressing time was 48 hours at a temperature of 20°C and an average pressure of 0.7 MPa.

For hot bonding, a KB-3 type adhesive with a plasticity of 480 MPa was used. During hot bonding, the cross-sectional surfaces of the samples were cleaned with sandpaper. Bonding was carried out at a pressure of 1.0 MPa and a temperature of 100°C. The test results are presented in Table 1.

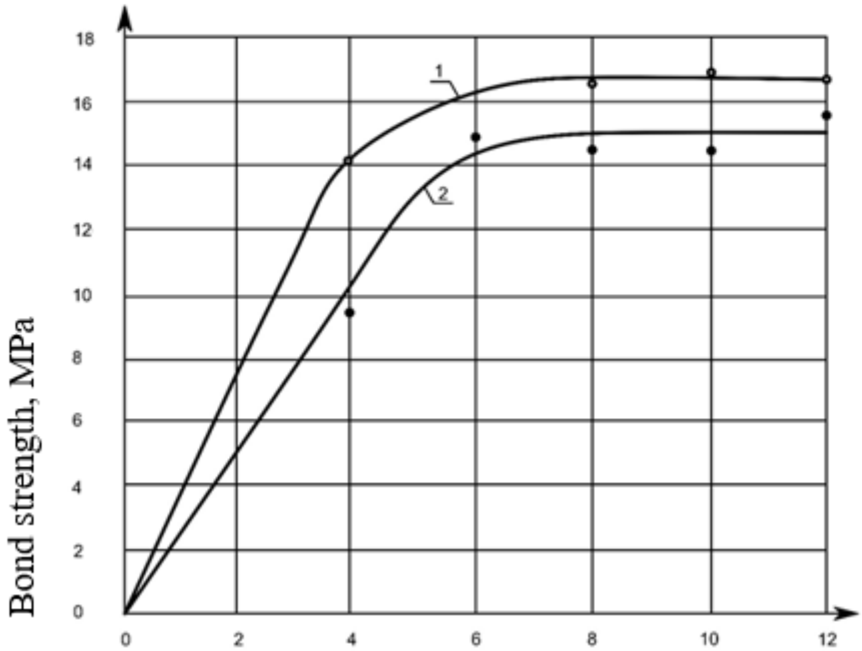

Figure 2. The effect of relative pressure on the strength of modified samples:
1 – regular birch boards glued together; 2 – modified birch boards.

According to the results of the experiment (Table 1), it was found that the reduction in the strength of the modified adhesive joint to a certain level, compared to the joint of natural materials, is due to the decreased strength of the wood under the influence of moisture. This indicator can also be considered as a measure of durability. The obtained results on the strength of the adhesive joint from the modified material (V = 20.7–25.7%) can be explained by the fact that the variability of the characteristics (V = 8.5–17.6%) is due to the uneven distribution of adhesive on the cross-sectional surface of the modified material. When hot bonding modified materials, the strength values are higher than when cold bonding. The variability of the results is lower than in the "cold case." In particular, the ability to level the bonded surfaces, that is, improving the uniformity of the adhesive adhesion due to surface treatment, allows reducing the glue consumption to 200–250 g/m².

Results of static testing of the adhesive joint strength of bonded different samples.

Table 1

№	Name of the bonded material	Test Results			Indicator, C
		M	V	A	
Pine samples, KB-3 cold-setting adhesive					
1	Natural	9,3	11,2	86	0,37
2	Modified	7,7	22,7	32	0,73
Birch samples, KB-3 cold-setting adhesive					
1	Natural	9,1	17,6	50	0,33
2	Modified	8,4	25,7	40	0,67

Pine samples, FR-12 cold-setting adhesive					
1	Natural	9,3	10,7	88	0,51
2	Modified	5,6	26,5	25	0,70
Birch samples, FR-12 cold-setting adhesive					
1	Natural	6.2	24,4	25	0,80
2	Modified	8,1	22,6	60	0,76
Birch samples, KB-3 hot-setting adhesive					
1	Natural	13,7	8,5	-	0,52
2	Modified	13,3	20,7	-	0,78

Note:

M - strength of samples during cleavage at the adhesive joint, MPa (average value of results obtained from 10 samples);

V - coefficient of variation, %;

A - indicator of sample failure in the wood, %

Recommendations based on the experiment results:

Air temperature: 18°C.

Moisture content of bonding surfaces: 6-8%.

Surface smoothness: Class 5.

Adhesive viscosity at 20°C: 90-150 seconds.

Adhesive shelf life at 20°C: 2-4 hours.

Average adhesive consumption: 230 g/m².

Relative pressure: 1.0 MPa.

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