DETERMINATION OF GLUE JOINT SHEAR STRENGTH OF THERMALLY MODIFIED PINE (PINUS SILVESTRIS) AND BIRCH (BETULA PENDULA) IN COMPARISON WITH THE UNMODIFIED WOOD

Elena Vladimirova
Moscow State Forest University
Department of Technology of woodprocessing industries,
1st Institutskaya street, 1,
141005, Mytischi, Moscow region, Russia
Tel.: +79067831747, e-mail: egvl@mail.ru

ABSTRACT

The aim of this study was to determine the glue joint shear strength of thermally modified pine (Pinus silvestris) and birch (Betula pendula) in comparison with the unmodified wood and to look at the possibilities of its simultaneous gluing on the same equipment in the same conditions. For the experiments used two types of glue: polyvinylacetate glue (PVAc) Kleiberit 303.0 and polyurethane glue Kleiberit PUR – 501.0. Afterwards glue joint ultimate strength in shear parallel to the grain was measured.

Key words: thermally modified wood, glue joint, shear strength, birch, pine

INTRODUCTION

In recent years woodworking industry shows interest in composite materials from wood. One of such interesting materials can be made from thermally modified wood. Thermally modified timber can be glued together or with unmodified wood.

However there are many open questions about gluing of thermally modified wood for Russian manufactures. Among them are the type of the glue that can be used and the difference of this process with the classical gluing of unmodified wood.

Some research of thermally modified wood gluing was made by Technical Research Centre of Finland (VTT). VTT has studied the glueability of heat-treated wood with 1- component PVAc adhesives, 1-component polyurethane adhesives (PUR). The glueability test was carried out in accordance with DIN 68603. The strength of the glue line was determined in accordance with EN 392 (block shear test). Heat-treated wood absorbs water and water-based adhesives, such as PVAc, slowly. That is why longer pressing times than normal are needed when using water-based adhesives. When one works with PVAc adhesives, the water content in adhesive should be minimized.

It is reported that PUR (polyurethane) adhesives work well with ThermoWood. Although all tests carried out with PUR adhesives have been successful, it must be kept in mind that the curing reaction of PUR requires water. The water can be absorbed from either the wood or the surrounding air. The required amount of moisture is dependent on the adhesive, but if both wood and air are very dry, there exists the possibility of unsuccessful gluing [Anonymous, 2003].

VTT gives some recommendations about gluing of thermally modified wood (trademark ThermoWood). We made the tests with Russian thermally modified wood (trademark Vacuum Plus). The aim of this study was to determine the glue joint shear strength of thermally modified wood pine (*Pinus silvestris*) and birch (*Betula pendula*) in comparison with the unmodified wood and to look at the possibilities of its simultaneous gluing on the same equipment in the same conditions using two different types of glue.

EXPERIMENTAL METHODS

The pine *(Pinus silvestris)* and birch *(Betula pendula)* wood specimens used in this study were obtained from the wood producing manufacture „Beavers" Konakovo, Tver region, Russia.

Birch and pine wood was harvested for the company in the spring of 2012 in the Perm region, Russia. Boards with dimensions 30x90x3000 mm (thickness x width x length) were taken after preliminary drying in the convection kiln (Fig.1). Drying took place during one month, at 35–60 ºC. Humidity of timber after drying was 12 %.

Figure 1: Boards after convective drying

After that one half of boards were thermally modified with the technology called VACUUMTERM (Russian trademark Vacuum Plus). The process of thermal modification was held in a cylindrical vacuum kiln SPVT – 6. The temperature in the kiln brought to the level of 175 ºC for 96 hours. Then for 12 hours boards were thermally modified at this temperature. Further the kiln was turned off and cooling during 60 hours (Fig. 2).

Figure 2: Boards after thermal modification

The whole process of thermal modification took 7 days. After the thermal modification, the boards were visually evaluated for twists, cracks and other deformations. Only those boards that were free of defects were selected for further testing. The moisture content (MC) of thermally modified boards was measured to be about 4 %. The untreated wood of the same species was used as a control.

The specimens for all research were cut from thermally modified and unmodified boards, according to Russian standard GOST 16483.0-89 [GOST 16483.0-89].

The birch and pine wood glue joint were glued with two types of glue. The polyvinylacetate glue (PVAc), commercially named Kleiberit 303.0 (D3) – one-component glue and polyurethane glue (PUR), commercially named Kleiberit PUR – 501.0 (D4) - moisture curing, one-component reactive glue based on polyurethane, the top group of water resistance.

Prepared specimens were glued as recommended by the manufacturers (Table 1).

Table 1: Gluing characteristics

Type of glue	Viscosity	Press pressure	Glue spread	Open time of glue	Time under the pressure	Time of addition al gluing	Required by climatic conditions, temperature, moisture content	
	[mPa.s]	[N/mm^2]	[g/m^2]	20 [°C]	20 [°C]		T [°C]	MC, [%]
PVAc 303.0	13.000±2.000	0.7-1	150-200	6-10 min	20 min	2-3 hours	20	50
PUR 501.0	8.000	0.6	100-150	20-25 min	60 min	2-3 hours	20	50

After that wood glued joints specimen were prepared (Fig. 3) according to the GOST 15613.1-84 [GOST 15613.1-84]. Also, the moisture content of specimens was determined [GOST 16483.7-71].

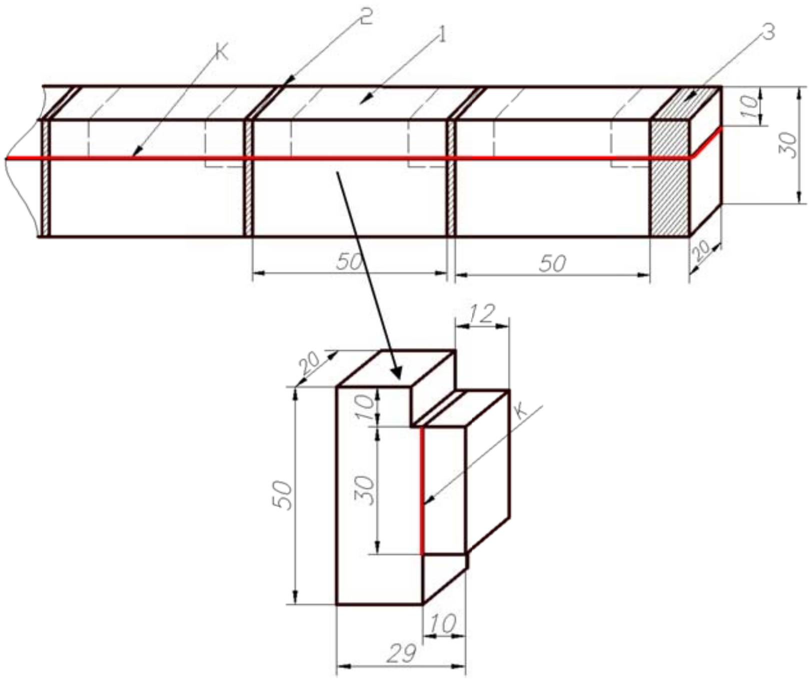

Figure 3: Dimension specimens according to GOST 16483.0-89.
1 - a blank for the specimens, 2 - cut, 3 - handling allowance

The calculation of the minimum number of specimens was carried out according to GOST 16483.0-89 at a confidence level of 0.95 and a relative accuracy of the specimen average of 5 %. The number of 38 specimens for each wood species was accepted.

The glue joint breaking tests were conducted in accordance with GOST 15613.1-84 [GOST 15613.1-84]. The specimens were mounted in a test machine ZD10/90 (Fig. 4, Fig. 5). The device with the specimen set there in was placed on the support platform of the testing machine so that the axis of the punch tool coincides with the axis of the charging device testing machine. The specimen was loaded at a rate of continuously moving the loading head testing machine (0,60 ± 0,15) mm / min.

Figure 4: Device for testing

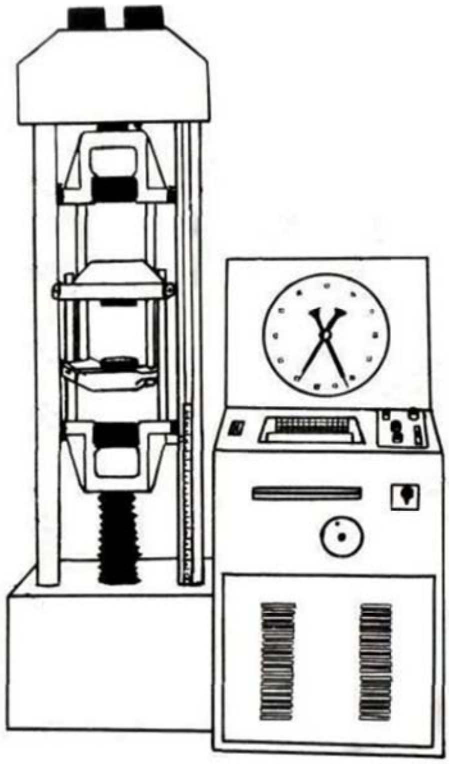

Figure 5: Test machine ZD10/90

RESULTS AND DISCUSSION

Glue joint ultimate strength while shearing along the grain (τ) is calculated in MPa (kgf/cm^2), rounded up to 0.1 MPa (1 kgf/cm^2) using formula

$$\tau = \frac{P}{b \cdot l}, \qquad (1)$$

where P – breaking load, N (kgf);

b – width of shearing area of the specimen, m (cm);

l – length of shearing area of the specimen, m (cm).

The strength of glue joints, according to the requirements of GOST 20850-84 [GOST 20850-84], should be not less than 6.0 MPa, with an average of not less than 8.0 MPa. The tests continued until the complete destruction of the specimen. The result should be the arithmetic mean of the tensile strength of all tested specimens (of one type), the type of failure was also fixed. Table 2 presents the results obtained for shear strength.

Table 2: Test results

Type of glue	**Failure load P, N**	**Ultimate strength, MPA**	**Moisture content,**	**The destruction of wood,**
	[kgf]	[kgf/cm^2]	[%]	[%]
Pine				
PVAc, UM*	4,90	7,84	12,00	62
PVAc, TM**	3,47	5,69	4,00	53
PUR, UM	4,83	7,87	12,00	53
PUR, TM	2,11	3,44	4,00	29
Birch				
PVAc, UM	7,19	11,54	12,00	83

PVAc, TM	4,60	7,63	4,00	53
PUR, UM	8,24	13,24	12,00	83
PUR, TM	2,11	3,47	4,00	15

* UM – unmodified wood

** TM – thermally modified wood

During the test, the joints failed in three different ways (Fig. 6). With the PVAc and PUR glue, in unmodified pine and particularly in unmodified birch, the failure was usually 100% in the wood. With the PVAc glue, in thermally modified wood both in birch and pine showed some combination of both types of failure. With the PUR glue, in thermally modified wood both particularly in birch the failure was 85 % along the glue line and combined.

Figure 6: The types of failure

The average value of the failure load in the experiments with unmodified pine wood was 7,84 MPA (PVAc) and 7,87 MPA (PUR) and with unmodified birch wood was 11,54 MPA (PVAc) and 13,24 MPA (PUR). Thermally modified wood glued with PVAc has the average value of the failure load 7,63 MPA – birch and 5,69 MPA – pine. All results, except for the last conform to standards specified in GOST 20850 - 84 [GOST 20850-84]. It seems likely that it should be taken into account that thermally modified wood absorbs slowly water and water based glues, such as PVAc. That is why sometimes longer pressing times than normal is needed and the results can be better.

Thermally modified wood glued with PUR has the values of the failure load 3,47 MPA – birch and 3,44 MPA – pine that significantly below the standards specified in GOST 20850 – 84 [GOST 20850-84]. There appear to be that when using PUR glues, it has to be kept in mind, that the hardening reaction of PUR needs water. The water can be absorbed either from the wood or surrounding air. If both wood and air are very dry, gluing may fail [Anonymous, 2003].

From these data we can conclude that the moisture of thermally modified wood is not enough to get a proper gluing joint. And the simultaneous gluing of thermally modified and unmodified wood with using two different types of glue needs to take additional measures. In particular the recommendations of FTA, should take into account. From this it follows that for a complete reaction (crosslinking) of PUR glue, and to achieve the desired curing glue joints in articles the moisture content of wood should be 12 ± 3% , or thermally modified specimens should be moisturized additionally to rise the moisture content of the surface. To clarify the recommendations for gluing of thermally modified wood it is reasonable to continue research in this direction.

CONCLUSIONS

The results found in the present study allow drawing the following conclusions:

1. The average value of the failure load in the experiments with unmodified wood conform to standards specified in GOST 20850 - 84.
2. The thermal modification reduces the equilibrium moisture of content, and shear strength of wood glued with PVAc and PUR glues.
3. The results show that there are some differences in the processes of gluing and strength characteristics of unmodified and thermally modified wood.
4. The simultaneous gluing of thermally modified and unmodified wood with using two different types of glue needs to take additional measures.
5. It should be taken into account that thermally modified wood absorbs slowly water and water based glues, such as PVAc. That is why sometimes longer pressing times than normal is needed and the results can be better.
6. When using PUR glue for a complete reaction (crosslinking), and to achieve the desired strength of the glue joints the moisture content of wood should be 12 ± 3%, or thermally modified wood should be moisturized additionally to raise the moisture content of the surface.

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