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Investigations of strength and water-resistance of EPI adhesives glue lines formed on thermo-ash wood

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Abstract: *Investigations of strength and water-resistance of EPI adhesive's glue lines formed on thermo-ash wood.* The aim of the work was determined the gluability of the thermally modified ash wood (*Fraxinus excelsior* L.) with the use of EPI adhesive. For the realisation of the experimental part, ash wood was thermally modified in technological conditions in the "Sawmill - Stefan" Company in Wloszakowice, at two temperatures (192 and 200°C). The resulting products marked under the trade names "amber" and "cognac" respectively. Values of MC of modified wood were in the range 5±1%, however the density ranges for "amber" were - 610±90 kg/m^3, and for "cognac" - 600±150 kg/m^3 respectively. The gluability for 5 variants (not modified ash - not modified ash, not modified ash-ash modified "cognac", not modified ash-ash modified "amber", ash modified "cognac" ash modified "cognac", ash modified "amber"-ash modified "amber") was determined. For investigations the strength of glue lines samples were prepared according to EN 12765 standard.

Keywords: thermo-ash wood, EPI adhesive, glue line, strength, water-resistance

INTRODUCTION

The basic idea of thermall treatment of wood is to improve its overall properties. Thermal modification is a process that improves the properties of wood without the use of chemicals. Only elevated temperatures and water vapour are needed to change the chemical composition of wood, leading to a reduction in hygroscopicity and an improvement in the biological durability and dimensional stability of wood (Hill 2006). Various wood species with distinct chemical compositions also behave differently during the thermal modification process (Militz 2002, Windeisen et al. 2007). On an industrial scale the process of heat-treated wood was developed by VTT in cooperation with the Finnish wood products industry. The process called ThermoWood® has been patented by Viitaniemi et al. (Boonstra and Tjeerdsma 2006). Thermowood material is manufactured with both coniferous and deciduous wood species.

The property of the wood surface of absorbing water or other liquids into it has an effect on its paintability and gluability (Sernek et al. 2008, Metsä-Kortelainen and Viitanen 2012). Besides these improvements, modification can change the strength of adhesion as a result of changes in chemical, physical and structural characteristics of wood. The bonding characteristic of modified wood becomes a complex issue due to large diversity of wood species, adhesives, and modification methods (chemical, thermal, etc.). ThermoWood® is a material that slowly absorbs water, and thus also water-based adhesives. The drying time of the binder is increased even 6-times compared to the unmodified timber. The quality of thermally modified wood bonding is acceptable when using PUR adhesives. For the application of various PVAC adhesives, there was a significant reduction in the strength of glue lines during the using which was explained by a lower affinity of adhesive to the surface of the modified wood (Anonymous 2003, Reinprecht and Vidholdová 2011). Problematic aspects of the gluability of modified wood were considered also in our division (Proszyk et al. 2011a, b). An interesting alternative to conventional bonding agents seems to be EPI- based adhesives, which offer several advantages. Dispersion EPI adhesives due to its unique properties deserve special attention. They are products finding application in difficult

conditions, that is where is required higher resistance to heat, humidity and chemical agents. They have good adhesion to most species of wood, and the ability for bonding plastics or metals. Other advantages of EPI adhesives are permitted to cold also they are capable of rapid crosslinking (even at room temperature), at elevated temperature they have a low level of creep, and provide a clear glue line.

MATERIALS

Ash wood (*Fraxinus excelsior* L.), was thermally modified in technological conditions at the "Sawmill - Stefan" Company in Wloszakowice at two temperatures (192 and 200°C). The obtained products are marked under the trade names "amber" and "cognac" respectively. MC values of modified wood were in the range 5±1%, whilst the density ranges for "amber" - were 610±90 kg/m^3, and for "cognac" - 600±150 kg/m^3. For the experiments EPI adhesive was chosen. The properties of glue lines were determined on block samples with dimensions 50x50x40 mm according to PN-B-03156. Sawn timber intended for prepare the samples shortly before gluing has been subjected to mechanical treatment (sawing and planing) which resulted in a small planks with dimensions of 320x50x20 mm. Then on the surface was applied the EPI adhesive in an amount of ca. 150 g/m^2, according to the manufacturer's instructions. After taking into account the open assembly time (maximum value specified by the manufacturer) sets were formed and were placed in hand-held screw-clamp for 24 h. After this time they were taken up, and then conditioned for seven days (20±2ºC, RH 65±5%), after which the block samples were obtained.

The gluability for 5 variants (in parentheses adopted marking system) was determined:

- not modified ash-not modified ash (A – A)
- not modified ash-ash modified "amber" (A – B)
- not modified ash-ash modified "cognac" (A – C)
- ash modified "amber"-ash modified "amber" (B – B)
- ash modified "cognac"-ash modified "cognac" (C – C).

Table 1. Description of durability classes of glue lines acc. to the PN-EN 12765

Durability class	Examples of climatic conditions and fields of application
C1	Interior, in which the moisture content of the wood does not exceed 15 %.
C2	Interior with occasional short-term exposure to running or condensed water and/or to occasional high humidity provided the moisture content of the wood does not exceed 18 %.
C3	Interior with frequent short-term exposure to running or condensed water and/or to heavy exposure to high humidity. Exterior not exposed to weather.
C4	Interior with frequent long-term exposure to running or condensed water. Exterior exposed to weather but with protection by an adequate surface coating.

For investigations the strength of glue lines samples were determined according to EN 12765 standard (Tables 1 and 2). All variants from the experiment were divided into four subgroups for the different pre-treatments. For study used 10 samples for each test. An adhesive was classified in accordance with Table 1, which gives examples of climatic conditions and fields of application in which the bonded member is to be used. All the shear tests were carried out on a ZDM 5/91 universal testing machine according to the standard, immediately after the pre-treatments had been performed. Rate rise of load was 5 mm/min. Samples were mounted in an additional instrumentation (guillotine), which was placed in the work testing unit. Statistical calculations were made after rejection two extreme results. For

evaluation, the WFP (wood failure percentage) indicator was accepted, WFP indicator for glue lines after the destructive loadings were interpreted with 5% graduations (100 – only in wood, 0 – only in adhesive layer).

Table 2. Pre-treatments and durability classes of the glue lines acc. to the PN-EN 12765 standard

Conditioning sequences		Adhesive strength in N/mm^2 Durability classes			
Test number	Duration and condition	C1	C2	C3	C4
1	7 days in standard atmosphere	≥10	≥10	≥10	≥10
2	7 days in standard atmosphere, 1 day in water at 20±5 °C	-	≥7	≥7	≥7
3	7 days in standard atmosphere, 3 h in water at 67±2 °C, 2 h in water at 20±5 °C	-	-	≥4	-
4	7 days in standard atmosphere, 3 h in boiling water, 2 h in water at 20±5 °C	-	-	-	≥4

RESULTS

Results of the strength of glue lines are presented in Table 3.

Table 3. Results of strength's tests of glue lines acc. to PN-EN 12765 standard

Adopted marking system	Test number (acc. to Table 2)	Statistical datas *)				WFP
		$x_{max.}$	$x_{min.}$	$x_{av.}$	v	
		[MPa]			[%]	
A-A	1	18.80	14.12	17.18	10.85	50
A-C		25.54	0.78	11.53	74.43	50
A-B		19.24	16.58	18.01	6.70	75
B-B		14.11	9.44	11.13	16.14	75
C-C		14.39	10.34	11.56	14.00	100
A-A	2	16.04	3.31	10.31	47.47	0
A-C		10.17	5.46	7.82	21.11	0
A-B		8.70	7.61	8.16	5.99	25
B-B		9.56	7.33	8.35	11.48	25
C-C		4.39	1.33	3.30	41.24	0
A-A	3	0.42	0.71	0.16	49.14	0
A-C		1.15	0.01	0.61	67.59	0
A-B		2.51	1.25	1.68	42.40	0
B-B		4.47	1.45	2.76	44.19	0
C-C		4.74	2.91	3.82	33.91	0
A-A	4	0.30	0.10	0.20	0.20	0
A-C		1.15	0.01	0.61	67.59	0
A-B		1.37	0.69	0.98	28.57	0
B-B		1.54	0.80	1.03	31.51	0
C-C		1.64	1.32	1.50	10.65	0

*) $x_{max.}$ – maximum value, $x_{min.}$ – minimum value, $x_{av.}$ – arithmetic average, v – coefficient of correlation,

WFP – wood failure percentage

The general analysis of results of the strength from the Table 3 proves, that glue lines from the EPI adhesive fulfilled requirements within the range the casual strength (test no. 1), exceeding criteria requirements.

After the test 2 variant A-A was ranked at a high level (10.31 MPa). Thermoash wood glued in variants A-C, A-B, B-B was characterized with the strength within the range 7.82-8.35 MPa. The connection of the not modified ash wood with modified slightly lowered the discussed parameter in comparison with the variant A-A. It was observed low values of the WFP indicator.

The data analysis of the strength values of the glue lines after waterborne tests 3 and 4 acc. to PN-EN 12765 standard proves, that as opposed to the test 2 maximum values reached the C-C variant (appropriately 3.82 and 1.50 MPa). For all samples delaminations in the adhesive layer was observed. The large differentiation of the results after waterresistance tests was observed. There testify about this high values of the coefficient of correlation exceeding in many cases level 20%.

In Table 5 summarize results of the evaluation point of susceptibility to bonding the thermo-ash wood using EPI adhesive selected in the aspect strength and resistance test of glue lines.

Table 5. Evaluation scale of resistance of glue lines from EPI adhesive

Adopted marking system	Test number (acc. to the Table 3)				Total points
	1	2	3	4	
	Points				
A-A	5	5	1	1	12
A-B	5	5	2	1	13
A-C	5	5	1	1	12
B-B	5	5	3	2	15
C-C	5	3	4	2	14

In light of the adopted scale tested variants total can achive a maximum 20 points. The results of calculations for variant B-B resulted 15 points, which means that it showed the highest efficiency for bonding thermally modified ash wood. However, this received only 75% of the maximum number of points. On this calculation mostly influence results of strength after test no. 1. Without this test no 1. all tested variants obtain points within the range 7-10 points, which is also an unsatisfactory result. In this context exists the therefore continuous necessity of the conduct of further investigations of the gluability of thermally modified ash wood.

CONCLUSIONS

Based on the results of the experiments and the adopted criteria for their evaluation it was stated that:

1. Glue lines from the EPI adhesive fulfilled requirements within the range the casual strength (test no. 1), exceeding criteria requirements.
2. Used for the experiments EPI adhesive due to the unsatisfactory waterresistance of obtained glue lines did not receive a recommendation for bonding thermally modified ash wood exposed to changeable hydro-thermal conditions.
3. The adopted punctual scale of evaluations can be use for evaluation of the quality of glue lines.

REFERENCES

1. ANONYMOUS (2003): ThermoWood Handbook. Finnish Thermowood Association, c/o Wood Focus, Helsinki, Finland, 66.
2. BOONSTRA, M. J.; TJEERDSMA, B. F. (2006): Chemical analysis of heat treated softwoods. Holz als Rohund Werkstoff 64: 204-211.
3. HILL C.A.S. (2006): Wood modification: chemical, thermal and other processes. Wiley, Chichester.
4. METSÄ-KORTELAINEN S, VIITANEN H. (2012): Wettability of sapwood and heartwood of thermally modified Norway spruce and Scots pine. Eur. J. Wood Prod.70: 135–139.
5. MILITZ, H. (2002): Thermal treatment of wood. European processes and their background. International Research Group on Wood Preservation. Doc. No. IRG/WP 02-4021.
6. PROSZYK S., LIS B., KRYSTOFIAK T., ŁAKOTA M. (2011a): Studies upon wettability of solidified isocyanate adhesives layers formed on thermally modified ash wood (*Fraxinus excelsior* L.). Ann. WULS – SGGW. For. And Wood Technol., 75, 231-235.
7. PROSZYK S., KRYSTOFIAK T., LIS B., ŁAKOTA M. (2011b): Studies upon gluability of thermally modified ash wood with the use of adhesives based on isocyanates. Proc. IX. Symposium Selected processes at the wood processing 07-09.09.2011 Šturovo, 206-217.
8. REINPRECHT L., VIDHOLDOVÁ Z. (2011): Termodrevo. ŠMIRA- PRINT, s.r.o., Česká Republika: 89.
9. SERNEK M., BOONSTRA M., PIZZI A., DESPRES A., GERARDIN P. (2008): Bonding performance of heat treated wood with structural adhesives. Holz als Roh u. Werkst, 66: 173-180.
10. WINDEISEN E., STROBEL C., WEGENER G. (2007): Chemical changes during the production of thermotreated beech wood. Wood Science and Technology 41 (6): 523-536.

Streszczenie: *Badania wytrzymałości i wodoodporności spoin z klejów EPI uformowanych na drewnie termo jesionu.* Celem pracy było określenie podatności na klejenie jesionu modyfikowanego termiczne klejami EPI. Do badań użyto próbek blokowych wg ASTM D 905-86. Określono wytrzymałość uzyskanych spoin uwzględniając testy wodoodpornościowe w klasie C wg PN-EN 12765. Badania przeprowadzono na próbkach blokowych klejonych w pięciu układach wg ASTM D 905-86. Jako kryterium oceny jakości zastosowany został wskaźnik WFP, a dla dokładniejszego wyspecyfikowania różnic dokonano oceny matematycznej na podstawie zaproponowanej punktowej skali ocen. Na podstawie wyników przeprowadzonych badań stwierdzono, że spoiny z kleju EPI nie spełniły wymagań w zakresie wodoodporności spoin i w tym kontekście istnieje konieczność prowadzenia dalszych badań podatności na klejenie drewna modyfikowanego termicznie.

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