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THE INFLUENCE OF VENEER MODIFICATION ON ADHESIVE BOND STRENGTH

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ABSTRACT

A major problem in the manufacture of three-dimensional laminated veneer products is damage due to stretching and/or buckling of the veneer. To reduce or eliminate this problem a modification of the veneer could be a solution, but the modification may also lower the quality of the adhesive bond. The purpose of this study was to investigate how different modifications influence the adhesive bond strength between the veneers. Three different modifications were studied: 1) surface veneer pre-bonded with paper and hot melt adhesive under a surface pressure of 1.8 MPa at a temperature of 130°C; 2) veneer pre-bonded with polypropylene fabric glued to the veneer with an urea formaldehyde (UF) adhesive system under a surface pressure of 1.0 MPa at a temperature of 80°C; 3) densified veneer. An unmodified veneer was tested as a reference. The modified veneers were bonded to an unmodified veneer with an UF adhesive system under a surface pressure of 1.5 MPa at a temperature of 90°C. Determination of tensile shear strength was performed in an ABES testing machine as a single lap joint test directly after bonding and after climate cycling. The results showed that veneer pre-bonded with polypropylene fabric and UF adhesive gave a weak glue-line, indicating that the pre-bonded veneer with polypropylene fabric and UF adhesive impairs the bonding. The other groups showed no significant difference from the reference veneer in tests before climatic cycling. The climate cycling deteriorated the adhesive bonds slightly for specimens pre-bonded with both paper and polypropylene fabric.

Key words: densification, pre-bonding, open system, THM processing, veneer, wood adhesive bonds

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INTRODUCTION

Moulded and laminated veneer products consist of veneers bonded together with adhesive into predetermined shapes. These products have many advantages; laminating veneer makes it possible to create a great variety of high strength components for use in furniture, interior fittings, and constructions. A major problem in the manufacture of laminated veneer products is that the veneers may stretch and/or buckle under moulding, which can result in damage to the product. The degree to which a veneer can be shaped during moulding depends, for example, on veneer thickness and preparation, type-related properties, product design, and the mould itself. Bending in one direction is not difficult, as long as the mould remains open. Here, “open” means an arc with a length less than half the circle’s circumference. In 2-D moulds, the radius should not be less than 30 times the veneer thickness. In 3-D moulds, much greater skill is required, since there is a risk that the laminate may break due mainly to the anisotropic structure of the wood, its low transverse tensile strength and its low strain to failure in tension. It is possible to modify veneers in four different ways to prevent undesired veneer deformations or cracking while moulding: 1) veneers can be formatted by removing unnecessary parts of the veneer in areas prone to problems of stretching and/or buckling while moulding. 2) a fabric, mesh, paper, or other material can be bonded to the back of the veneer to strengthen it in the transverse direction; a method often used for the visible, outermost veneers of thin or brittle type of veneers. 3) a ‘3-D veneer’ can be formed extremely three-dimensionally. The most well-known 3-D veneer was developed by Reholz GmbH and later introduced onto the market (Müller 2006). During the production of a Reholz 3-D veneer, narrow grooves spaced 0.1 to 1 mm apart are cut through the thickness of the veneer. To keep the strips together, lines of glue are spread on the rear of the veneer. 4) the veneer is modified before moulding by thermo-hydro, thermo-hydro-mechanical, or chemical action (Navi and Sandberg 2012). Traditionally, heat and moisture have been the most common way to soften wood and make it more susceptible to shaping. In the thermo-hydro and thermo-hydro-mechanical processes, the glass transition temperatures (Tg) of the different amorphous components of wood are a key factor for a good result, and the temperature for shaping should be selected according to two criteria. First, the minimum temperature at which the wood can be shaped is at least 25°C higher than the Tg of the lignin, i.e., approximately 110°C under moisture-saturated conditions and approximately 140°C at 80% ambient relative humidity (e.g. Huttunen 1973). Second, the maximum temperature, usually considered to be 200°C when air is saturated, must be sufficiently low to ensure that thermal degradation of the wood components does not occur. The thermo-hydrous window for the process of forming wood is thus limited to a temperature range from 110 to 140°C and a relative humidity range from 80 to 100%. Under these conditions, lignin, hemicelluloses and the semi-crystalline cellulose are relatively mobile. It is also possible to plasticise wood with chemical additives, which has been attempted using different chemicals with various results. Most promising has been the use of anhydrous ammonia. A method using hydrazine (N_2H_4) was patented by Huttunen (1973). Hydrazine is highly toxic and is derived from the same chemical processes used to manufacture ammonia (Navi and Sandberg 2012).

The aim of the present paper is to show how different modifications of veneers affect the bond-line strength.

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MATERIAL AND METHODS

The material used for the study was a rotary-cut veneer of beech (*Fagus silvatica* L.). Three different modifications of the veneers were evaluated relative to an unmodified reference:

1. Veneer pre-bonded with paper (Veneer backer VC300+, PWG VeneerBackings GmbH) that included a hot-melt adhesive and was applied to the veneer at a pressure of 1.8 MPa at 130°C.
2. Veneer pre-bonded with polypropylene fabric (Spunbond 50 gram, Scandinavian Nonwoven Ltd.) glued to the veneer with an UF adhesive system (Casco Adhesives Inc.) composed of resin part 1274 and hardener 2584 at a surface pressure of 1.0 MPa at 80°C.
3. Densified veneers.
4. Unmodified veneers (reference).

The veneer in Group 3 was densified at a surface pressure of 8.9 MPa at 100°C for 1 minute, after the veneers has been conditioned to 20% moisture content. The veneers were compressed and, after the spring-back on unloading, the remaining compression was 50% of the original veneer thickness.

To avoid failure in the wood material during the tensile shear strength test, the unmodified parts of the samples were strengthened with a paper of the same type used in group 1 glued on the flat side of the wood (Table 1). Each group was divided into two subgroups designated A and B. Subgroup A was tested in a sequence controlled by the testing machine directly after bonding and cooling and group B was climate cycled after bonding before the final tensile shear strength test, see Table 2 for details. Each subgroup consisted of 10 replicates. In all 80 replicates were tested.

Table 1. Design of the specimens in the different test groups. P'V and VP' – unmodified veneer strengthened with paper.

Group No.	Type of modification	Order of different material in the specimens in relation to the tested bond line (BL)
1	Paper-reinforced veneer(PV)	P'V – BL – PV
2	Fabric-reinforced veneer (NWV)	P'V – BL – NWV
3	Densified veneer (DV)	P'V – BL – DV
4	Reference veneer (V)	P'V – BL – VP'

The tensile shear strength test was performed in an automated bonding evaluation system an ABES testing machine (Adhesive Evaluation Systems, Inc.), shown in Figure 1. The test was a single lap joint test in principle similar to EN 205 (2003) with modifications regarding dimensions. Table 2 shows the parameters used in the test.
After testing, the mode of failure was determined, defined as wood failure, wood/fibre failure, fibre failure, fibre/adhesion failure or adhesion failure. A microscopy study will be performed to yield a better understanding of failure mode.

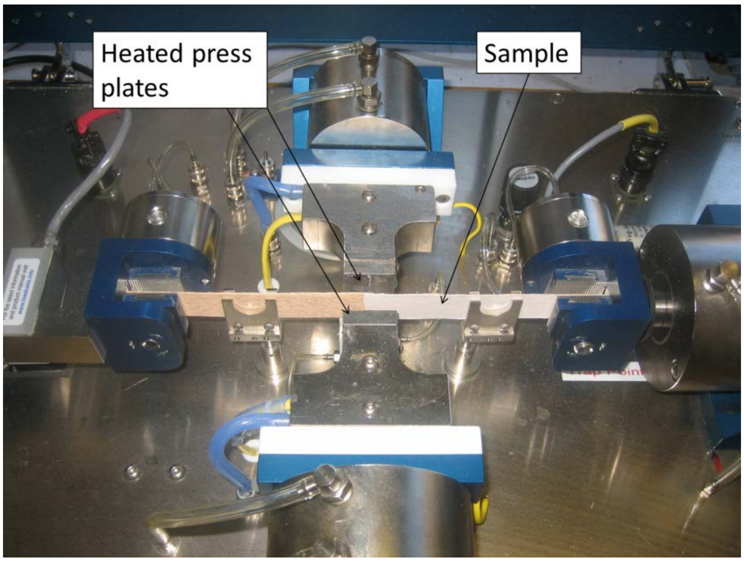

Figure 1. Automated bonding evaluation system testing machine

Table 2. Parameters for the tensile shear strength test. Subgroup A was tested in a sequence controlled by the testing machine and group B was climate cycled after bonding before the final tensile shear strength test.

Parameter	Quantity	Comment
Sample size (mm)		
Length of test piece	231	
Length of test slip	117	
Length of overlap	3	
Width	20	
Thickness	0.4/0.2	Unmodified/densified
Bond area (mm^2)	60	Overlap 3 mm
Adhesive in bond line (BL)		UF adhesive system (Casco Adhesives Inc.) resin 1274 and hardener 2584
Adhesive quantity (g/m^2)	150	
Pressing		
Temperature (℃)	90	
Pressure (MPa)	1.5	
Duration (s)	60	
Subgroup A		
1.Cooling time before tensile test (s)	30	With air
Subgroup B		
1.Climate cycling at 20°C (days)	4/5/32	at 20%/85%/20% relative humidity

RESULTS AND DISCUSSION

Table 3 shows the results of the tensile shear strength test. There was no difference in adhesive bond strength of the modifications in Groups 1 and 3 and the reference specimens (Group 4). The specimens with fabric-reinforced veneers (Group 2) had a significantly lower strength, for both subgroups of specimens. The climatic cycling influenced the adhesive bonds for both Group 1 and Group 2 and reduced the bond strength.

Table 4 shows the different types of failure that occurred in the bond-line (BL in Table 1). Wood failure means that the bond was stronger than the wood sample and that failure occurred only in the wood; fibre-failure means a bond failure with the wood fibres remaining at the failed surface; and adhesion failure means that the adhesive did not maintain adhesion between different parts of the sample. Wood adhesive bond failure can be divided in adhesive failure (glue on both sides), adhesion failure (glue on one side and wood on the other side) and wood/fibre failure where failure occurred in the interphase of wood and adhesive. There is also mixed failure where several of the listed types interact. All the samples in group 2 exhibited adhesion failure, probably because the fabric-reinforced veneer specimens were pre-bonded with UF, a chemically curing adhesive that provides a smooth surface that the new adhesive finds difficult to wet and penetrate. The mode of failure changed in group 1 after the climate cycling. Adhesion and fibre failure occurred in most samples in subgroup B and paper fibres were present on the failed surface of the samples, as shown in Figure 2. Only Group 3 showed results similar to those of the reference samples regarding bond strength and failure type, both before and after climatic cycling.

Table 3. Results of the tensile shear strength test. SD – standard deviation, P, NW; D, R, see Table 1

		Subgroup A		Subgroup B	
Group	Type of modification	Strength (MPa)	SD	Strength (MPa)	SD
1	Paper-reinforced veneer(PV)	8.9	1.1	8.0	1.1
2	Fabric-reinforced veneer (NWV)	5.3	1.0	4.3	0.9
3	Densified veneer (DV)	9.7	1.8	9.8	1.8
4	Reference veneer (V)	9.7	1.7	9.9	1.5

Table 4. Type and number of failures in tensile shear strength test for specimens tested directly after pressing (Subgroup A) and specimens cycled in changing RH (Subgroup B)

	Subgroup A				Subgroup B			
Group No.	1	2	3	4	1	2	3	4
Type of failure								
Wood	2	0	4	1	0	0	1	0
Wood/Fibre	0	0	3	4	0	0	1	3
Fibre	3	0	3	4	0	0	7	7
Fibre/adhesion	4	0	0	1	1	0	1	0
Adhesion	1	10	0	0	9	10	0	0

Figure 2. Bond surface with paper fibres after failure

CONCLUSIONS

The results of the adhesive bond tests on different combinations of modified veneer show that the bond strength is:

1. not influenced by pre-bonding of the surface veneers with paper, but this type of modification showed a lower strength after climate cycling
2. lower for a veneer strengthened with polypropylene fabric than for the reference
3. not influenced by densification of the veneer

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