SHEAR STRENGTH IN THE GLUE LINE OF *Eucalyptus* sp. AND *Pinus* sp.WOOD[1]

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ABSTRACT – To evaluate the adhesive efficiency on the union of glued joints in a particular temperature and humidity conditions for a specified time the adhesive must be submitted to specific load tests, such as shear in the glue line. The objective of this study was to evaluate the shear strength in the glue line of *Eucalyptus* sp and *Pinus* sp.woods. Five adhesives (castor oil, sodium silicate, modified silicate, , PVA and resorcinol-formaldehyde), three weights (150 g/m^2, 200 g/m^2, and 250 g/m^2) and two species (*Eucalyptus* sp. and *Pinus* sp.) of wood were used. Twelve specimens were obtained from each repetition per treatment, corresponding to 108 specimens that were conditioned at a temperature of 23 ± 1°C and relative humidity of 50 ± 2%. The interaction between the weight and type of adhesive was significant for the shear strength in the glue line of eucalyptus wood. However, no interaction between the weight and the adhesive was found for pinus, only the isolated from the adhesive effect. Chemical bonds originated in the polymerization of resorcinol-formaldehyde adhesives and castor bi-component conferred upon these adhesives the greatest resistance in the glue line. Castor and resorcinol-formaldehyde adhesives showed the highest shear strength values in the line of glue and wood failure. Castor adhesive presented satisfactory performance for bonding of eucalyptus and pine woods.

Keywords: Adhesives; Collage; Weight.

RESISTÊNCIA AO CISALHAMENTO NA LINHA DE COLA DAS MADEIRAS DE Eucalyptus sp. E Pinus sp.

RESUMO – Para avaliar a eficiência do adesivo na união das juntas coladas, sob uma determinada temperatura e condições de umidade, durante um tempo específico o adesivo deve ser submetido a testes de carregamento, como, por exemplo, o teste de cisalhamento na linha de cola. Portanto, o objetivo deste trabalho foi avaliar a resistência ao cisalhamento na linha de cola de amostras de madeiras de Eucalyptus sp. e Pinus sp. coladas com cinco diferentes adesivos (Bicomponente de mamona, silicato de sódio, silicato modificado, PVA e resorcinol-formaldeído) e três gramaturas (150 g/m^2, 200 g/m^2 e 250 g/m^2) . Foram obtidos 12 corpos de prova para cada repetição por tratamento, correspondendo a 108 corpos de prova por tratamento, totalizando 3240 corpos de prova, que foram condicionados a temperatura de 23+1° C e umidade relativa de 50 + 2%. Após atingirem a umidade de equilíbrio higroscópico, a resistência ao cisalhamento e a falha na madeira foram determinadas, nas condições seca e úmida. Foram ensaiados doze corpos-de-prova, sendo nove na condição seca e três na

condição úmida. As ligações químicas originadas na polimerização dos adesivos de resorcinol-formaldeído e bicomponente de mamona conferiram a estes adesivos maiores resistências ao cisalhamento na linha de cola e falha na madeira.

Palavras-chave: Adesivos; Gramatura; Colagem.

1. INTRODUCTION

In the wood-glue line system, the tensions generated in the bonded product are extremely important in the overall balance of the strength. The higher the glue line strength in relation to wood strength, the higher the percentage of breakage or failures in the wood at the interface with the glue line. Tensions generated in the glue line are manifested through shear stresses in the adhesive bonding plane and perpendicular to it (PINTO, 2011).

The function of an adhesive, in addition to joining two substrates, is to flow and to fill empty spaces between the joints to be glued, which reduce the distance between them, causing interactions between the adhesive and the substrate (PIZZI, 1994).

To evaluate the adhesive efficiency on the union of bonded joints under a particular temperature and humidity conditions during a specific time, the adhesive must be evaluated by means of specific loading tests, such as shear in the glue line. The adhesive transfers the load of an adherent to another by surface bonding. The resistance of the unions of the wood pieces per adhesive depends upon the strength of each element involved in the union. Many adhesives are reactive polymers and change from liquid to solid by means of several polymerization reactions. The adhesive has the function of establishing chemical bond between the pieces of wood (CARNEIRO, 2010).

The region of the glued joint must be free of defects such as knots and irregular fibers, which reduce the physical and mechanical resistance of the bonded product. In mechanical tests on glued wood, the adhesive strength and the glue line quality are evaluated. Bonding quality depends not only on the adhesive but also on the wood species, weight, applied pressure, bonding temperature, techniques for obtaining the joint, cleaning of the glue surface and wood surface quality (NASCIMENTO et al., 2001).

Some norms evaluate the bonding quality of the wood such as North-American D905-98 and D2339-98 norms, which focus on the procedures for determining the wood adhesion capacity, and both require that the results of the tests are reported on the strength of the glued joints and on wood failure percentage as well as the variability of the results (ASTM, 2000).

In addition, according to ASTM D2559-99 and D5771-99 norms, which provide the specifications required for the structural and non-structural use of laminated wood, respectively, the evaluated samples must have at least 75 and 60% of wood failure, respectively. High values for the failure percentage in the wood are indicative of good adherence quality since they evidence that the cohesion of the adhesive and the strength of the adhesive-wood interface are higher than the resistance of the wood itself (ASTM, 2000).

However, low failure percentage indicates that the use of wood is not being optimized by the application of adhesive in the tests in the breakage occurs at lower tensions than the resistance of the wood. Eventually, the reproducibility of the results of the joint strength and wood failure percentages is what will indicate the suitability of using a particular adhesive for bonding a particular species of wood. Studies on the bonding conditions such as temperature, pressure, surface treatment, and so one, may improve adhesion performance (DELLA LUCIA; VITAL, 1981).

The objective of this study was to evaluate the shear strength in the glue line of *Eucalyptus* sp. and *Pinus* sp.

2. MATERIAL AND METHODS

The experiment was conducted in Laboratório de Painéis e Energia da Madeira and in Laboratório de Propriedades da Madeira, both at Federal University of Viçosa, in Viçosa, State of Minas Gerais. Woods of *Eucalyptus* sp. and *Pinus* sp. from the region of the city and local shops were used, respectively. The woods were obtained in the form of boards, which were transformed into sheets of 40 cm in length x 10 cm in width x 0.6 cm in thickness. The sheets were dried in an oven until reaching 12% moisture content for a later collage. Basic density of the woods was determined

using the water immersion method, according to NBR 11941-02.

Five adhesives were used in the experiment: Resorcinol-formaldehyde, castor oil based polyurethane, sodium silicate, PVA (polyvinyl acetate) and modified-silicate starch. Resorcinol-formaldehyde and castor oil adhesives were provided by Momentive Química do Brasil LTDA. and by KEHL Indústria e Comércio LTDA., respectively. Sodium silicate adhesive and modified-silicate starch were supplied by Tubominas LTDA. industry. PVA adhesive was purchased in local shops.

Pinus and Eucalyptus sheets were chosen based on their mass, lack of defects and cleaning. Sheets were cleaned using sandpaper, which was slightly used on the surface of the wood for removal of residues; and a brush for dusting. Wood joints glued together with cold curing adhesives were pressed in manual press using calibrated torque wrench at a pressure of 12 kgf / cm^2, for closing the screws. The press consisted of three steel threaded bars to enable the application of the bonding pressure.

Three weights equal to 150, 200 and 250 g/m^2 were used and the amount of adhesive was quantified using a scale. The adhesive was spread on both sides of the sheets using a brush. Five minutes was the time considered for the assembly open time for all adhesives, except for castor oil polyurethane. Closing time for all adhesives was equal to 10 minutes. After that, the glued joints were taken to the manual press for 24 h. Once pressed, those joints were conditioned at room temperature until reaching equilibrium humidity (±+ 12%). The result was the production of 270 glued joints of two species, five adhesives and three weights with nine replicates of each treatment.

To determine the shear strength on the glue line and percentage of wood failure, the samples were cut according to ASTM (1993) D 2339/93 norm. Twelve specimens were obtained from each treatment replicate, corresponding to 108 specimens, which were placed in a temperature of 23 ± 1°C and relative humidity of 50 ± 2%. After reaching hygroscopic humidity equilibrium, shear strength and wood failure were determined in dry and wet conditions. Twelve specimens were tested, nine in the dry condition and three in the wet condition. Each specimen had its shear area measured with the aid of a caliper. In the wet conditions, the measurement was carried out before water immersion of the specimens at 20 ± 3°C for 24 h. Quality of glued joints was set in the shear test in wet condition according to NBR ISO 12466-1: 2006 norm, and the failure percentages in the wood were measured with the aid of checkered transparent blades, with their respective areas delimited in percentage. The experiment was set according to a complete factorial with two species (pine and eucalyptus), five types of adhesives (resorcinol-formaldehyde; castor oil bi-component, polyvinyl acetate, sodium silicate and silicate modified starch), three weights (150, 200 and 250 g/m^2),totaling 30 treatments in nine replications. Firstly, the data were submitted to Lilliefors and Cochran test, for normality and homogeneity of variances testing, respectively. Then, the data were submitted to analysis of variance (ANOVA) and when significant differences were set, the treatments were compared from each other by the test of Tukey at 95% of probability.

3. RESULTS

Weight and adhesive type interaction was significant for the shear strength in the glue line of eucalyptus wood in dry condition. However, no interaction between the weight and the adhesive was found for pinus, only the isolated effect of the adhesive.

A significant effect was found for the interaction between weight and type of adhesive for failure in eucalyptus wood, which was not found in pinewood, with only the isolated effect of the adhesive type, that is, no effect of weight was observed. Sodium-silicate based adhesives and modified silicate presented the lowest average percentages of wood failure in the dry condition.

No significant effect was found for the interaction between weight and type of adhesive regarded shear strength in the glue line of the woods, in the wet condition. Only the isolated effect of the adhesive type was observed, that is, no effect of weight was found. Oil castor adhesives and resorcinol showed the highest average values for the shear strength in the wood glue line, in the wet condition.

No significant effect was found for the interaction between weight and type of adhesive in the failure of eucalyptus and pine woods, in wet condition, showing

Table 1 – Shear strength average values (kgf/cm²), the wood of eucalyptus and pine, in the dry condition, depending on the weight and type of adhesive.
Tabela 1 – *Valores médios de resistência ao cisalhamento (kgf/cm²) da madeira de eucalipto e pinus, na condição seca, em função da gramatura e tipo de adesivo.*

Eucalipto	Adesivo					
Gramatura (g/m²)	Silicato de sódio	Mamona	Resorcinol	PVA	Silicato modificado	Média
150	23,3 Ba	75,7 Aa	91,8 Aa	71,0 Aa	30,4 Ba	58,4
200	23,1 Ba	74,7 Aa	83,2 Aa	75,2 Aa	30,1 Ba	57,3
250	36,4 Ca	65,0 Ba	62,8 Bb	86,7 Aa	40,7 Ca	58,3
Média	27,6	71,8	79,3	77,7	33,8	
Pinus	Adesivo					
Gramatura (g/m²)	Silicato de sódio	Mamona	Resorcinol	PVA	Silicato modificado	Média
150	3,5	47,7	37	45,9	24,1	31,6
200	6,8	43,2	35,9	48,5	25,9	32,1
250	3,2	45,9	46	48,5	29,3	34,6
Média	4,5 D	45,6 A	39,6 B	47,6 A	26,4 C	

Means along the lines followed by the same capital letters and along the columns followed by the same lowercase letters do not differ from each other (α = 0.05), by the Tukey test.
Médias ao longo das linhas seguidas de mesmas letras maiúsculas e ao longo das colunas seguidas de mesmas letras minúsculas não diferem entre si (α = 0,05), pelo teste de Tukey.

only the isolated effect of the adhesive type. Sodium silicate, modified silicate and PVA presented the smallest percentage of wood failure, being statistically equal to each other.

Oil castor adhesive penetrated in the eucalyptus wood vessels, forming hooks in the cell cavities, which may have contributed to its greater adherence.

4. DISCUSSION

Regardless the weight and type of wood used in the collages, sodium silicate and modified silicate adhesives showed the lowest shear strength values than the others. This is probably due to the chemical structure of silicate adhesive and its viscosity. This adhesive has weak bonds between silica and sodium

Table 2 – Average fault values (%) in the woods of eucalyptus and pine, dry condition, depending on the weight and type of adhesive.
Tabela 2 – *Valores médios de falha (%) nas madeiras de eucalipto e pinus, condição seca, em função da gramatura e tipo de adesivo.*

Eucalipto	Adesivo					
Gramatura (g/m²)	Silicato de sódio	Mamona	Resorcinol	PVA	Silicato modificado	Média
150	1,6 Ba	32,4 Aa	36,0 Ab	16,5 ABb	2,5 Ba	17,8
200	3,0 Da	51,7 ABa	31,8 BCb	62,1 Aa	3,7 CDa	30,5
250	4,5 Ba	30,5 Ba	72,5 Aa	61,5 Aa	4,8 Ba	34,8
Média	3,0	38,2	46,8	46,7	3,7	
Pinus	Adesivo					
Gramatura (g/m²)	Silicato de sódio	Mamona	Resorcinol	PVA	Silicato modificado	Média
150	0,0	35,9	80,1	38	2,6	31,3
200	0,0	48	71,9	54,2	5,9	36
250	0,0	60	85,3	38,3	7,9	38,3
Média	0,0 C	48,0 B	79,1 A	43,5 B	5,5 C	

Means along the lines followed by the same capital letters and along the columns followed by the same lowercase letters do not differ from each other (α = 0.05), by the Tukey test.
Médias ao longo das linhas seguidas de mesmas letras maiúsculas e ao longo das colunas seguidas de mesmas letras minúsculas não diferem entre si (α = 0,05), pelo teste de Tukey.

Table 3 – Shear strength average values (kgf/cm²) on the line of glue wood of eucalyptus and pine, humid conditions, depending on the weight and type of adhesive.
Tabela 3 – *Valores médios de resistência ao cisalhamento (kgf/cm²) na linha de cola da madeira de eucalipto e pinus, condição úmida, em função da gramatura e tipo de adesivo.*

Eucalipto	Adesivo					
Gramatura (g/m²)	Silicato de sódio	Mamona	Resorcinol	PVA	Silicato modificado	Média
150	0,0	52,6	72,9	21	0,0	29,3
200	0,7	61,3	69,6	22,8	0,0	30,9
250	0,0	49,6	57,1	22,2	0,0	25,8
Média	0,2 D	54,5 B	66,5 A	22,0 C	0,0 D	
Pinus	Adesivo					
Gramatura (g/m²)	Silicato de sódio	Mamona	Resorcinol	PVA	Silicato modificado	Média
150	0,0	28,1	33	3,7	0,7	13,1
200	1,0	31,8	37,6	2,7	0,0	14,6
250	1,6	30,9	37,6	2,3	0,0	14,5
Média	0,9 C	30,3 B	36,1 A	2,9 C	0,2 C	

Means along the lines followed by the same capital letters and along the columns followed by the same lowercase letters do not differ from each other ($\alpha = 0.05$), by the Tukey test.
Médias ao longo das linhas seguidas de mesmas letras maiúsculas e ao longo das colunas seguidas de mesmas letras minúsculas não diferem entre si ($\alpha = 0,05$), pelo teste de Tukey.

carbonate, also resulting in lower adhesion to the wood. The low viscosity of silicate may have caused an over penetration of the adhesive in the cavities in the wood and generated a "thin", even "hungry" glue line, possibly not enough to promote adhesion on the glue line.

Oil castor, resorcinol-formaldehyde and PVA adhesives presented the highest shear strength values in the wood glue line in dry condition. Such fact may be attributed to the chemical composition of these adhesives, for example, resorcinol-formaldehyde, which is derived from condensation reactions between resorcinol and formaldehyde, producing not only high mechanical resistance bounds, but also resistance to water and to climate variations (PIZZI, 1994). However, oil castor adhesive showed strength in the glue line due to the urethanes monomers produced by the reaction of hydroxylated compounds with isocyanates. In addition to the urethane groups, the polyurethanes may contain aliphatic and aromatic hydrocarbons, ester and ether groups, urea, amide, among others (AZEVEDO, 2009).

Table 4 – Percentage failure values in eucalyptus wood, wet condition, depending on the weight and type of adhesive.
Tabela 4 – *Valores porcentuais de falha na madeira de eucalipto, condição úmida, em função da gramatura e tipo de adesivo.*

Eucalipto	Adesivo					
Gramatura (g/m²)	Silicato de sódio	Mamona	Resorcinol	PVA	Silicato modificado	Média
150	0,0	18,4	41,5	2,7	0,0	12,5
200	0,0	27	38,6	0,7	0,0	13,3
250	0,0	22,9	72,3	1,4	0,0	19,3
Média	0,0 C	22,8 B	50,8 A	1,6 C	0,0 C	
Pinus	Adesivo					
Gramatura (g/m²)	Silicato de sódio	Mamona	Resorcinol	PVA	Silicato modificado	Média
150	0,0	10,9	63,0	0,0	0,1	14,8 a
200	0,0	20,3	66,1	0,5	0,0	17,4 a
250	0,0	8,9	60,5	0,0	0,0	13,9 a
Média	0,0 C	13,4 B	63,2 A	0,2 C	0,0 C	

Means along lines followed by same capital letters do not differ from each other ($\alpha = 0.05$), by Tukey's test.
Médias ao longo das linhas seguidas de mesmas letras maiúsculas não diferem entre si ($\alpha = 0,05$), pelo teste de Tukey.

Regarding PVA, water is removed from its composition during its polymerization, wherein the chemical structure is joined, forming a homogeneous and continuous glue line, providing collage shear strength and elasticity of the adhesive joint.

This study found that Eucalyptus joints glued together with the resorcinol-formaldehyde adhesive were more resistant to shear in dry condition. Yet, pine joints glued together with oil castor and PVA adhesive showed a higher shear strength, not differing from each other, but those glued with resorcinol-formaldehyde showed less resistance.

Low strength of resorcinol adhesive is likely due to the applied pressure of 12 kgf/cm^2, which may have been excessive, that is, since pine wood is more permeable, a greater penetration of resorcinol adhesive on the wood occurred, which originated a thinner and with less resistance main glue line. Marcati and Della Lucia (1996), when studying the behavior of *Anadenanthera macrocarpa* (Benth) Brenan to adhesion with PVA and resorcinol-formaldehyde, found that resorcinol adhesive gave the highest strength to the glued wood in relation to PVA, where the value found was equal to 143.5 kgf/cm^2. According to these authors, resorcinol adhesive increased the resistance in relation to PVA, as a structural adhesive.

When evaluating the quality of joints of *Eucalyptus grandis*, *Eucalyptus saligna* and *Pinus elliottii* woods glued with polyvinyl acetate and resorcinol-formaldehyde, Vital et al. (2006) found that the higher average values of shear strength were obtained in the joints produced with *Eucalyptus saligna* wood. According to these authors, the different behavior of each adhesive within each wood species is possibly due to the variability in density and permeability of each wood.

Beraldo and Dias (2010), when evaluating the shear strength of polyurethane adhesive (castor oil) in *Pinus ellioti*, found the 1.5:1 ratio (polyol/hardener), the same proportion used in this work, which showed shear strength in the dry test equal to 65.77 kgf/cm^2.

With regard to the weights used in the experiment, it was found, in the joints of eucalyptus glued together with the castor and resorcinol adhesives that the increase in the weight caused a significant reduction in shear strength in the glue line. That was not observed in the glued joints of pine. This can be explained, probably, by the characteristics of the adhesives, such as viscosity and working time, and also by the thickness of the glue line of the adhesives. Castor adhesive showed high viscosity and rapid polymerization reaction, resulting in less working time, which makes the spreading in wood difficult for the glue; and, probably a pre-polymerization of the adhesive takes place, contributing to the reduction of shear strength in the glue line. However, resorcinol-formaldehyde adhesive showed a longer working time and higher fluidity in the wood, facilitating the collage; nevertheless, it showed less thickness of the glue line when a heavier weight was used, which promotes greater penetration of resorcinol in the vessels and rays of the eucalyptus woods, as weight was increased, which may have contributed to the lower adhesion in the glue line.

When studying the effect of the weight on the shear strength in the glue line of two tropical woods, Santos and Del Menezzi (2010) found that the adhesive of resorcinol-formaldehyde at 200 g/m^2 weight was not effective in bonding the evaluated species.

Teles et al. (2010) studied the effect of weight on the quality of glued joints, and found that the efficiency and quality of the adhesion of the resorcinol-formaldehyde adhesive was influenced by weight and showed an increase in joint strength bonded with the increment of the weight of the adhesive, where the greatest resistance was obtained with the weight of 300 g/m^2.

It was found in this work that the increase in resorcinol-formaldehyde adhesive weight decreased shear strength in the glue line. The resorcinol adhesive glue line decreased as the weight increased, that is, a greater penetration in the cell cavities of the wood occurred, forming a "thiner" main glue line. During pressing of the glued joints of eucalyptus and pine, an excess of resorcinol adhesive was found at the edges of the woods as weight was increased, emphasizing that, it could be seen that pine is more permeable than eucalyptus wood. It is worth mentioning that the weight is an important factor when working with collage of wood since it depends on the moisture content of environment and the wood, as well, the viscosity of the adhesive, the type of wood and the applied pressure, and these factors will influence the resistance the joint and the quality of the glued product.

In a study on laminated glued Eucalyptus wood doors, Petrauski (2012), using adhesives based on resorcinol and castor oil, found that variations in the weights of oil castor and resorcinol of 200, 250 and 300 g/m^2 had no significant effect on strength of the glued joints.

Joints glued with resorcinol-formaldehyde adhesive showed the highest wood failure percentage, both in the dry and the wet conditions. This is probably due to its high reactivity in function of its chemical structure because the presence of hydroxyls in the resorcinol aromatic ring contributed to an enhanced binding with the hydroxyls present in the wood, increasing the chemical adhesion. In chemical bonding, the basic forces involved are the primary chemical bonds between the adhesive and the adherent, which is responsible for strength and duration of the adhesive bond (PIZZI; MITTAL, 1994).

Petrauski (2012) found that the wood failure percentage in the joints glued with resorcinol-formaldehyde was affected by the weight. In addition, both PVA adhesive and castor-based adhesive presented the highest percentages of failure in eucalyptus wood when using a weight of 200 g/m^2. The largest castor adhesive failure percentage is probably due to the chemical bonds between the polyol and isocyanate and mechanical adhesive hooking. This adhesive forms crossed bounds with the hydroxyl groups of the wood during the polymerization of polyol and isocyanate. The crossed bounds are important in polyurethane post-curing since it increased the strength of the polymer.

By using castor based adhesive with a weight of 160g/m2, Petrauski et al. (2010) observed wood failure percentages lower than 50%. Nevertheless, Vital et al. (2006) obtained the lowest percentage of failure in joints glued with resorcinol-based adhesive, in comparison with the PVA. However, in this work, wood failure percentages were higher when compared to the PVA adhesive for resorcinol adhesive in dry conditions. This is probably due to the high viscosity of the PVA adhesive, which hampered its spread in the wood, damaging the movement and mobility functions of the adhesive, and also due to the fact that the resorcinol is a structural adhesive, presenting chemical bonds with the wood during polymerization, which give to this adhesive a greater adherence in the glue line.

Sodium silicate, modified silicate and PVA adhesives showed the lowest shear strength values in the glue line for the glued joints with eucalyptus and pine, evidencing the low resistance of these adhesives to water. Therefore, they should not be used in high relative humidity environments or in direct contact with water. It is important to mention that many specimens bonded with these adhesives were delaminated when immersed in water for 24 h. it should be highlighted that all specimens of eucalyptus wood bonded with the modified silicate adhesive delaminated, which made impossible to perform the test.

Castor and resorcinol adhesives showed the highest average values for shear strength in the wood glue line in the wet condition. Renzo (2008), when studying the structural panel of parallel sheets (PLP) of *Eucalyptus grandis* using resorcinol, tannin and castor oil derived polyurethane adhesives, found that the values found for the shear property in dry, wet and post- boiling conditions, in the treatments with castor adhesive were satisfactory when compared to resorcinol adhesive.

In relation to castor adhesive, moisture resistance is likely due to the intercrossing of chemical bonds and to the flexibility of the chains plus the intermolecular forces, originating themselves in polymers ranging from linear to flexible, to highly interlocked rigid and moisture resistant (AZEVEDO, 2009). With respect to the resorcinol-formaldehyde adhesive, it is worth

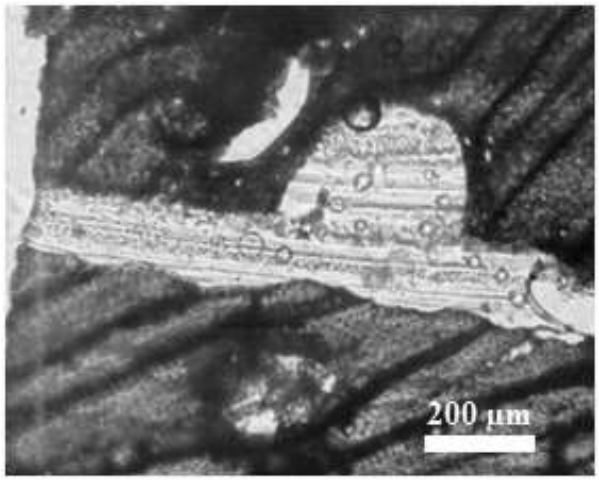

Figure 1 – Glue line after polymerization castor adhesive (eucalyptus wood).
Figura 1 – *Linha de cola do adesivo de mamona após a polimerização (madeira de eucalipto).*

mentioning that during the polymerization reaction, cross-links are formed which provide greater reactivity to the adhesive and its moisture resistance (PIZZI; MITTAL, 1994).

Castor and resorcinol adhesives differ significantly from each other, where the joints of eucalyptus and pine glued with resorcinol-formaldehyde showed the highest wood failure percentage in wet condition. Resorcinol-formaldehyde adhesive stands any condition to which it may be exposed, even under climate changes. This type could attend market needs since it is a waterproof adhesive and can be cured at room temperature, with high structural strength, overcoming the wood's itself (JESUS, 2000).

Overall, according to several authors, polyurethanes resins present high moisture resistance as a characteristic. However, the average values of wet wood failure observed in this study were lower than those of resorcinol-formaldehyde. This is probably due to the high viscosity of the adhesive, causing poor fluidity, resulting in the difficulty in spreading over the wood and compromising the adhesive bond. Another important fact is the rapid reaction between polyol and the hardener agent (isocyanate), which may have caused the adhesive pre-curing before it migrated into the wood. The bi-component polyurethane adhesives have rapid cure at room temperature and may present incomplete cure when the polyol and the hardener agent are not properly mixed (FRIHART, 2005).

Beraldo and Dias (2008) evaluated the castor adhesive performance in relation to resorcinol under three proportions of polyol/isocyanate mixture in the manufacture of joints for air dried, saturated and after boiling wood. These authors found that castor adhesive performance was inferior to that of resorcinol and recommended the use of castor adhesive at 1.5:1 (polyol: isocyanate) ratio.

When studying the behavior of castor adhesive in laminated and glued wood, Jesus and Calil Júnior (2002) found that the castor based polymer penetrated into the micro and macroanatomical wood structures, strengthened it and leading to the occurrence of its rupture in the innermost region in the wood-adhesive interface.

5. CONCLUSION

Chemical bondings originated in the polymerization of resorcinol-formaldehyde adhesives and castor bi-component gave higher strength in the glue line for this adhesives.

The type of adhesive used has a significant effect on the values of shear strength and failure percentage (wet condition) of Eucalyptus and Pinus glued joints.

Castor and resorcinol-formaldehyde adhesives showed the highest shear strength values in the glue line and wood failure. In addition, castor adhesive presented relevant performance on the collage of eucalyptus and pine woods.

The 250g/m^2 weight used for resorcinol-formaldehyde promoted a thinner glue line and higher percentages of wood failure in the dry condition.

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