Specie – treatment - adhesive combinations for glulam purpose

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Abstract

Glued laminated timber is an engineered product that requires precision manufacturing in all its stages. The finished product can only be tested in laboratory conditions. However, it is necessary to have quality control in the production to ensure that the properties of the glulam are appropriate to the product specified requirements in accordance with the standards. In Brazil is still no specific standard of qualification for the manufactures of Glulam. In this context, different kinds of wood, adhesives and preservative treatments in the composition of Glulam can be used. This paper aims to evaluate the proposed trials conducted with combinations of four Brazilian reforestation species, three adhesives and three types of preservative treatment. As a result was observed that combinations, which showed the best performance, were *pine* and *parica wood,* with any type of adhesive or treatment investigated, which can be used in exterior applications. *Lyptus*® wood for any combination of treatments falls into the internal use class. *Teak* wood can be used indoors (adhesive polyurethane and all kinds of treatment) or external (phenol resorcinol formaldehyde adhesive and all kinds of treatment).
Keywords: Glued laminated timber. Treatment. Structural adhesives. Reforestation wood.

1 Introduction

Glued Laminated Timber (Glulam) is an engineered wood product that requires precision of manufacturing in all its stages. The finished product can only be tested under laboratory conditions. However, quality control is required in production to ensure that the properties of Glulam are appropriate to the resistance specified for the material by standards, and among these, the EN 386 (2001) standard can be cited. In the United States, the AITC (American Institute of Timber Construction) is the recognized institution to carry out the quality control program of structural wood. Some standards used ac-

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cording to this purpose are T102 (2004), T107 (2004) and T110 (2004). Besides, different kinds of wood, adhesives and preservative treatments in the composition of Glulam can be used. Thus, it is important knowing the adequate wood-specie-treatment combination more adequate for this purpose. Is important to say that in Brazil is still no specific standard of qualification for the manufactures of Glulam.

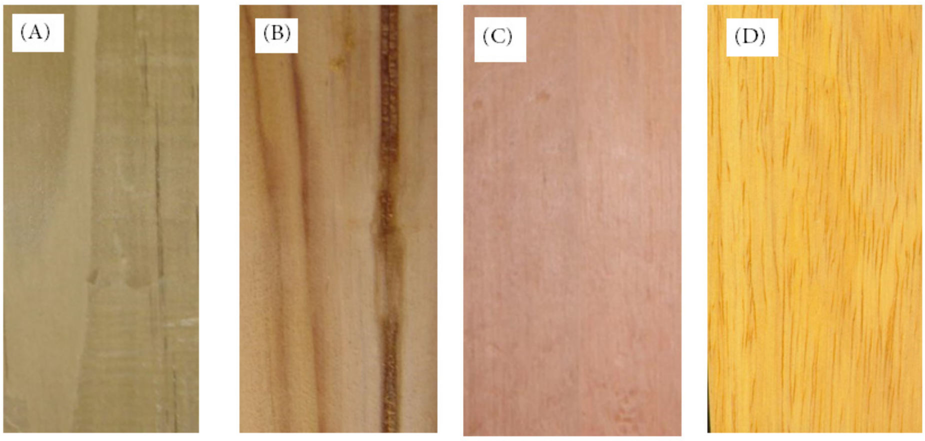
In 1948, through the Forest Service of the State of São Paulo, were the American species known as "*yellow pine*", which include *P. palustris*, *P. echinata*, *P. elliottii* and *P. taeda*, introduced for testing. Among these, the last two stand out for ease in cultivation, rapid growth and intense reproduction in the South and Southeast of Brazil. Since then a large number of species continued to be introduced and established in field experiments by government agencies and private companies seeking to establish commercial plantations.

The *Pinus oocarpa* is among the tropical pine species most widespread in the tropics. It is native to Mexico and Central America, with more extensive natural distribution northwest to southeast in the Pinus region. Apart from wood, *P. oocarpa* also produces resin in amounts feasible for commercial extraction. This species produces many seeds, which facilitates the expansion of its plantations.

Lyptus® is a wood considered noble, fully extracted from renewable forests, which ensures a reliable and environmentally sustainable supply. This is one of its main advantages over traditional hardwoods, such as mahogany, rosewood, ivory and walnut. Besides being environmentally friendly, *Lyptus*® is developed by crossing selected trees, which give more versatility, durability and beauty. *Lyptus*® cost is equivalent to that of other hardwoods.

The wood of *Tectona grandis*, can only be cultivated in tropical areas, but has great demand, especially in Europe, surpassing the price of mahogany. The *teak* wood is used primarily in the manufacture of window frames due to its weather resistance. It is also used in the production of furniture, vessels and decorations. It is a stable wood, with virtually no warping and contracting during drying and resistant to changes in humidity. This is an essential property in the case of doors, windows, drawers allowing them to open and close smoothly without difficulty. In Brazil, it is found in the states of Amazonas, Pará, Mato Grosso, and Rondônia, The wood is soft, light, heavy texture, grain straight to irregular, with a reddish cream heart and light cream sapwood. Figure 1 shows the kinds of wood used for Glulam.

Figure 1 – Species of wood for Glulam: (A) *Pine*, (B) *Teak*, (C) *Lyptus*® and (D) *Parica*.



The properties of wood have a clear effect on the adhesive. Hardwoods are generally more difficult to glue than softwood. The anatomical properties of wood have a significant influence on the bonding of wood, such as the variability in density and porosity, heartwood and sapwood and juvenile wood and mature wood. Furthermore, there is the influence of the dimensional instability of reaction wood, as well as the direction of the grain, in which the penetration relates to the cutting direction. (Albuquerque & Latorraca, 2005).

Among the species are also differences in the growth pattern of each tree. During the growing season, different cell types and sizes are formed. The adhesive should be chosen considering the weather conditions of use (use classes), the species of wood, the preservative used, and manufacturing methods.

According to NCh2148.cR2010 (2006) Chilean standard, the Use classes in which the structural elements are laminated are shown in Table 1.

Table 1 – Structural Use Classes

Use Classes	Description	Moisture of the wood	Temperature
1	Interior Exterior	≤12% ≤18% for wood without treatment	<50°C
2	Covered	≤20% for softwoods with treatment	<50°C
3	Exterior	Any	Any

The preservation of woods with the use of preservative treatments consists of impregnating wood with toxic substances, so that they can no longer be used as food for termites or fungi.

According to the NCh2148.cR2010 (2006), the preservative treatment of glued laminated wood must be performed after it is manufactured, checking the compatibility between the adhesive and the treatment to be used.

When the thinner dimensions of Glulam become the preservative treatment impossible, preserved wood should be used for their manufacture, the moisture content of the wood assembly must be controlled, and the compatibility of the preservative used with the adhesive in question should be checked. Therefore, the recommendations of the manufacturers of preservatives and adhesives should be followed for their compatibility.

According to Vick (1995), the commercial adhesives do not always adhere to wood treated consistently to meet industrial requirements as regards resistance to delamination.

Based on the above, in this work, shear strength, failure mode in the glue line, and delamination data are presented. These tests, in order to evaluate some combinations of adhesive/wood species/treatment, according to the ANSI / AITC A190 (2007) standardized specifications, were performed. For this purpose four reforestation wood species (*Pinus, Parica, Lyptus® and Teak*), three preservative treatments (CCA, CCB *Ox*, CCB *Salt*) and no treatment; and three adhesives (polyurethane HB S309, phenol resorcinol formaldehyde RS 216M and Melamine MUF 1242 / 2542) were used. About the treatments used, *Ox* means Oxide made with raw materials based on pure oxides, which guarantee the quality of a product with perfect percentages and the homogenization of the ingredients. *Salt* is a simple mixture of compounds in the form of salts, causing problems fixing boron.

2 Materials and methods

The four wood species passed through of a visual and mechanical classification, so that they could be assembled for producing Glulam. With the help of classification rules reference, the growth characteristics are used to select the timber classes of visual quality. Thus, visual grading of *pine* wood was performed according to the criteria adopted by the ABNT NBR 7190 (1997) Brazilian standard.

For the *teak* wood we tried to adapt this criteria for classification, because there is no visual grading criteria that specify the dimensions to be checked in hardwood timber. However, all the woods were also graded by the ABNT NBR 7190 (1997) Brazilian standard. The assembly process was the same for all species.

The average moisture content of the wood of 12% was used. The bonding with layers of wood without treatment using the two types of adhesives and the bonding was made no longer than 24 hours after the planning of wood was made.

Besides, up 180 to 200 g/m^2 of adhesive to one surface with the assemblies pressed at 1 MPa for 6 hours, according to manufacturer specifications, was applied in this case.

After the assembly, wood pieces were sent to a commercial treatment facility and treated with the following preservatives: CCA (chrome CrO_3 (47,5 %), copper CuO, (18,5 %) and arsênic As_2O_5 (34,0 %)); CCB ($CuSO_4$ (35,8%), H_3BO_3 (22,4%), K_2CrO_7 (38,5%) and $NaHSO_4$ (2,1%)) and CCBS (the

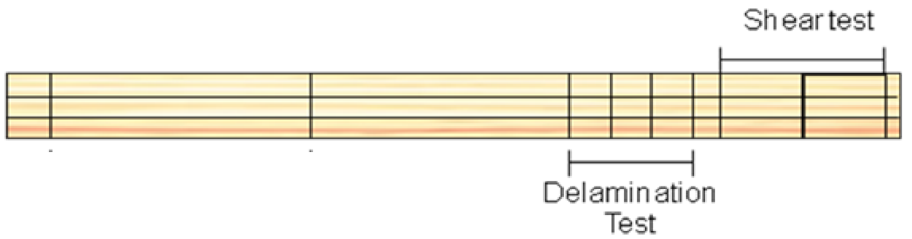
CCB-treated wood - Base Salina, proved that after 150 hours, about 85% of boron were leached and, moreover, leads to the formation of residues on the surfaces of treated wood, which may cause environmental contamination, and make it harder to finishes and collages). These treatments are the most commonly used in Brazil. The chemical treatment in an autoclave after seven days of adhesive curing, and conditioned to a relative humidity of 12% after preservative treatment was carried out.

The test methods followed ANSI/AITC A190 (2007) American normative specifications and the delamination tests followed the CSA 0112.10 (2006) Canadian standard.

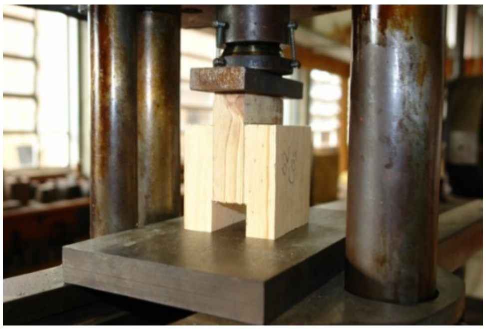
The glued assembly nominal dimensions, in this case, were 210 cm long, 10 cm wide and 4 cm thick. Five specimens from each assembly: one wet shear, one dry shear and three for the delamination test, were removed from the beam for the tests.

Figure 2 shows the configuration of the specimens obtained from glued assemblies and a shear test specimen is shown in Figure 3.

Figure 2 – Specimens obtained from glued assemblies.



Figigure 3 – Specimens for shear tests.



Fonte: Calil Neto (2011).

Figure 4 shows the apparatus of test used for delamination tests. The delamination test was performed with the use of autoclave in pressure and vacuum cycles.

Figure 4 – Delamination tests.

Fonte: Calil Neto (2011).

2.1 Classification criteria

The criteria considered for the "Use Classes" for acceptance of combinations of adhesive-preservative treatment were as follows:

- For the delamination test the CSA 0112.10 (2006) Canadian standard describes that the delamination of all glue lines of the wood specimen should not exceed 1%;
- For the shear test, the coefficient of variation is 28%, similar to that prescribed by the ABNT NBR 7190 (1997) Brazilian Standard. In this case, the failure modes must be considered;
- Specimens with a total break in the adhesive line tested in the dry condition were considered substandard;
- Specimens with a total break in the line of adhesive in a wet condition were classified as a class for "internal use".

3 Results and Discussion

For the realized tests, the shear strength (f_{v0}), the standard deviation (DP), the coefficient of variation (CV) and the failure mode (on wood or resin) were obtained. The main results of these tests are shown in Tables 2 and 3. The percentages of delamination referred to the each combination test, in this case, are also presented in Table 2 and 3. The highlighted numbers in Tables 2 and 3 exceed the values in analised standard.

3.1 About the use class

By the analysis of the Table 1 the *Pine* wood and *Parica* wood were considered, due to good results, for exterior use.

The wood of *Teak* with the adhesive polyurethane presented good results when analyzed at a humidity of 12%, but when saturated presented several anomalies in its coefficient of variation. Therefore, the use in this case was classified as interior. The same species with the adhesive phenol resorcinol formaldehyde had as good a performance when saturated as with 12% moisture and therefore was classified as exterior use.

The wood of *Lyptus*® presented many anomalies both at 12% moisture and when saturated. It also presented various expected failure modes and therefore was classified as interior use.

4 Conclusions

The proposed methodologies submitted for testing were satisfactory for the classification of the combinations of adhesive-species-preservative treatment.

It was also observed that the processing and handling of materials and adhesives require a very strict quality control, since these materials are very sensitive to variations in humidity, temperature, time and pressure.

The combinations which showed the best performance were wood of Pine with any adhesive type of treatment analyzed and can thus be used outside.

During the test the wood of *Parica* was attacked by termites, while the other woods in the same area were not, meaning that *Parica* needs to be treated in order to have long time use.

The wood of *Lyptus*®, for any combination of adhesive treatment, is suitable for inside use.

The wood of *Teak* can be used inside (adhesive polyurethane and all kinds of treatment) or outside (adhesive phenol resorcinol formaldehyde and all kinds of treatment).

Table 2 – Results of the tests for *Pine* and *Parica* woods

Specie	Adhesive	Treatment	Delamination (%)	f_{vo} (MPa) 12%	DP	CV	MR	f_{vo} (MPa) Saturated	DP	CV	MR
Pine	Polyurethane	No	0.5	7.03	0.87	12.38	Wood	3.11	0.45	14.60	Wood
		CCA	0.0	4.93	0.44	9.02	Wood	2.62	0.28	10.64	Wood
		CCB	0.7	5.82	1.17	20.09	Wood	2.59	0.69	26.74	Wood
		CCBS	0.9	5.01	0.23	4.69	Wood	2.93	0.15	4.95	Wood
	Phenol resorcinol formaldehyde	No	0.6	5.63	0.46	8.17	Wood	4.09	0.24	5.92	Wood
		CCA	0.7	5.76	0.45	7.84	Wood	4.10	0.51	12.56	Wood
		CCB	0.6	7.05	0.40	5.60	Wood	4.86	0.65	13.44	Wood
		CCBS	0.0	7.73	1.07	13.81	Wood	5.97	0.95	15.84	Wood
	Melamine formaldehyde	No	0.3	7.01	0.45	12.23	Wood	3.01	0.55	10.55	Wood
		CCA	0.2	7.52	0.54	10.38	Wood	2.99	0.68	5.65	Wood
		CCB	0.4	6.22	0.33	5.85	Wood	2.76	0.77	6.54	Wood
		CCBS	0.4	7.34	0.75	6.78	Wood	2.58	0.85	13.52	Wood
Parica	Polyurethane	No	0.0	5.06	0.48	11.29	Wood	2.12	0.44	14.80	Wood
		CCA	0.1	5.50	0.55	9.40	Wood	2.15	0.29	10.98	Wood
		CCB	0.0	4.83	0.77	25.47	Wood	2.33	0.67	11.95	Wood
		CCBS	0.0	5.04	0.33	5.05	Wood	2.77	0.57	5.98	Wood
	Phenol resorcinol formaldehyde	No	0.1	5.95	0.41	7.05	Wood	3.95	0.40	6.85	Wood
		CCA	0.0	5.86	0.59	9.53	Wood	3.56	0.55	15.35	Wood
		CCB	0.2	6.05	0.51	10.95	Wood	3.99	0.47	12.85	Wood
		CCBS	0.0	5.78	0.25	8.56	Wood	4.08	0.98	12.11	Wood
	Melamine	No	0.3	5.05	0.54	12.23	Wood	3.55	0.52	11.12	Wood
		CCA	0.5	5.12	1.10	10.23	Wood	2.45	0.85	10.17	Wood
		CCB	0.0	6.09	0.78	9.86	Wood	3.89	0.36	9.56	Wood
		CCBS	0.1	5.45	0.89	4.56	Wood	2.15	0.45	8.86	Wood

MR: mode of failure
f_{v0}: shear failure
DP: pattern deviation
CV: coefficient of variation
Highlighted number: exceed the standard

Table 3 – Results of the tests for *Teak* and *Lyptus* woods

Specie	Adhesive	Treatment	Delamination (%)	f_{v0} (MPa) 12%	DP	CV	MR	f_{v0} (MPa) Saturated	DP	CV	MR
Teak	Polyurethane	No	1.9	4.77	1.11	23.19	Wood	5.65	1.29	22.89	Wood
		CCA	2.8	6.78	0.72	10.60	Wood	4.95	1.08	21.89	Wood
		CCB	0.6	4.91	1.45	29.56	70%Adhe	4.09	0.90	21.95	Wood
		CCBS	0.0	7.23	0.29	4.05	Wood	5.02	1.47	29.40	Wood
	Phenol resorcinol formaldehyde	No	2.2	6.82	0.43	6.29	Wood	6.06	0.38	6.29	Wood
		CCA	0.0	5.98	0.60	10.03	Wood	3.10	1.03	33.14	Wood
		CCB	0.0	7.61	1.17	15.44	Wood	3.81	1.54	40.36	Wood
		CCBS	0.0	7.06	0.93	13.11	Wood	3.39	0.08	2.26	Wood
	Melamine	No	0.9	8.62	1.47	17.12	Wood	4.47	0.14	4.69	Wood
		CCA	0.5	6.31	0.65	12.12	Wood	4.77	0.45	4.56	Wood
		CCB	0.7	7.46	1.25	13.56	Wood	4.70	0.56	5.87	Wood
		CCBS	1.0	9.89	0.98	11.22	Wood	4.50	0.23	4.56	Wood
Lyptus®	Polyurethane	No	38.1	3.40	0.21	6.23	Wood	2.64	1.09	41.20	50%
		CCA	7.6	5.45	0.82	15.03	70%Adhe	3.54	0.78	22.02	Adhe
		CCB	4.7	3.13	0.49	15.80	Wood	1.66	0.37	22.06	50%
		CCBS	7.2	3.61	0.92	25.35	70%Adhe	2.64	0.58	21.86	50%
	Phenol resorcinol formaldehyde	No	38.6	4.10	0.98	23.95	Wood	2.03	0.59	28.87	50%
		CCA	11.1	2.77	1.02	36.84	70%Adhe	1.21	0.39	31.99	Adhe
		CCB	8.3	3.37	1.07	31.73	Wood	2.47	1.27	51.47	Adhe
		CCBS	8.9	3.96	1.37	34.47	70%Adhe	2.54	0.00	0.04	50%
	Melamine	No	23.2	6.88	1.11	17.25	Wood	3.71	1.14	23.35	50%
		CCA	15.3	5.14	1.58	10.56	70%Adhe	5.88	1.86	26.65	Adhe
		CCB	13.56	7.26	2.56	16.56	Adhe	5.61	2.56	16.65	50%
		CCBS	25.5	5.56	3.52	15.75	50%	4.56	3.56	20.56	50%

MR: mode of failure
f_{v0}: shear failure
DP: pattern deviation
CV: coefficient of variation
Highlighted number: exceed the standard

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References

ANSI. A190 – *American National Standard": Structural Glued Laminated Timber*. American Institute of Timber Construction. 2007.

ABNT. NBR 7190 - *Projeto de estruturas de madeira*. Associação Brasileira de Normas Técnicas. 1997.

ALBUQUERQUE, C.E.C.; LATORRACA, J. V. F. *Colagem varia de acordo com as propriedades da madeira*. Revista da Madeira, Edição 88. 2005.

AITC. T102 – *Adhesive Spread Measurement*. American Institute for Timber Construction. 2004.

AITC. T107 – *Shear Test*. American Institute for Timber Construction. 2004.

AITC. T110 – *Cyclic Delamination Test*. American Institute for Timber Construction. 2004.

CAN. 0112.10 - *Qualification Code for Manufactures of Structural Glued – Laminated Timber*. Canadian Standards Association. 2006.

CALIL NETO, Carlito. *Madeira laminada colada (MLC): controle de qualidade em combinações espécie-adesivo-tratamento preservativo*. M.Sc. Disssertation. Structural Department of São Carlos School of Engineering, EESC/USP, Brazil. 2011.

EN. 386 - *Glued Laminated Timber: performance requirements and minimum production requirements*. European Standards. 2006.

INN. NCh2148.cR2010 – *Madera: Construcciones en madera*. Instituto Nacional de Normalizacion. 2006.

VICK, C., B. Coupling agent improves durability of PRF bonds to CCA-treated southern pine. *Forest Products Journal*, v. 45, n. 3, 1995. p. 78-84.