# GLUE-LINE SHEAR STRENGTH BETWEEN THREE AMAZONIAN WOOD SPECIES WITH MDF AND OSB TO PRODUCE STRUCTURAL BEAMS

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**Abstract** Wood I-beam is a kind of engineered wooden product widely used in Europe and North America, although it is not well a known material in Latin America. It is composed by two main parts: flange and web. The flanges located on the top and bottom of the beam must resist compression and tension stresses. On the other hand, the web is responsible for resisting the shear stresses. Therefore, it is very important to provide a strong connection between these parts, and that is usually done using water-resistant and durable adhesives. In this context, the objective of this study was to evaluate the glue-line shear strength between three tropical hardwoods, castanha-de-macaco (*Cariniana micrantha*), cedroarana (*Cedrelinga catenaeformis*) and amapá (*Brosimum parinarioides*) and two types of panels (OSB, MDF).Two types of adhesives were tested: resorcinol-formaldehyde (RF) and castor oil-based polyurethane (PU). The adhesive spread rate was 350g/cm² and assembly pressure was 1N/mm². Afterwards, samples were cut and tested according to ASTM D905 (1994) to determine the glue-line shear strength ($f_{gv,0}$).The percentage of wood failure was calculated according to ASTM D5266 (2000). According to the results $f_{gv,0}$ values were statistically affected by species, adhesives and panel. The highest $f_{gv,0}$ values were obtained using cedroarana (2.6 N/mm$^2$), OSB (2.75 N/mm$^2$) and PU adhesive (2.56 N/mm$^2$).

**Keywords: resistance, glue line, tropical woods, adhesives, panels**

## 1. Introduction

Even producing 48.6million cubic meters of timbers per year, the Brazilian Amazon has little contribution in the wood market. The reason is the exploration concentrated in a few known species, absence of infrastructure and low quality of the wood due to low technological level. Consequently, there is a considerable waste, where only 30% of a log is used, 70% being discarded (CLEMENT & HIGUCHI, 2006). Increasing log yield, producing high quality pieces of solid woods and reconstituted ones, obtaining alternative products of wood using industry residues are paramount. Thereby, value is added to the final product made from innovative techniques.

Engineered Wood Products (EWP) consists of a viable alternative to concrete, demanding quality and high resistance to acquire market position. The Engineered Wood Association (APA, 2010) classifies EWP into four categories:

i. Structural Panels – Plywood and Oriented Strand Board (OSB);
ii. Glulam;
iii. Structural Composites – Laminated Veneer Lumber (LVL), Parallel Strand Lumber (PSL), Oriented Strand Lumber (OSL) and Laminated Strand Lumber (LSL);
iv. I-beams

I-beams are composed of wood and produced from the union of the structural panels on the web and solid wood or structural panels on the flanges. The development of this product occurred due to its performance. It’s a wooden structural member that offers strength, versatility and economy for use in residential and light commercial applications. The flanges resist common bending stresses, and the web provides outstanding shear performance, being better than lumber (SANTOS, 2008; APA, 2010).

Besides these features, the I-beams have dimensional stability; its structures are lightweight and easy to stick, allowing the passage of electrical gridand plumbing. However, they require a proper adhesion to ensure adequate performance (FISETTE, 2000). Thus, an essential part of the manufacturing process is the adhesive, defined as a substance capable of joining materials by the contact between their surfaces, permitting the construction of pieces through adhesive links (ASTM, 1994).

Based on the foregoing, this study aimed to evaluate the glue-line shear strength between three tropical hardwoods, castanha-de-macaco (*Cariniana micrantha*), cedroarana (*Cedrelinga catenaeformis*) and amapá (*Brosimum parinarioides*) and two types of panels (OSB, MDF) for Engineered Wood Products production, especially I-beams.

## 2. Material and Methods

### 2.1. Bonding Process

The woods, MDF and OSB used were purchased from the local timber market, Brasilia, Brazil. The timbers used were castanha-de-macaco – CM (*Cariniana micrantha*), cedroarana – CD (*Cedrelinga catenaeformis*) and amapá – AM (*Brosimum parinarioides*). The wood species were identified by a macroscopic analysis at the Wood Anatomy Laboratory (Forest Products Laboratory – Brazilian Forest Service /LPF - SFB).

The boards of the three species were transformed into twelve pieces of 700 x 60 x 20 mm (width x thickness x length) each, all in the tangential direction. Twenty-four pieces of equal size of MDF and OSB were obtained, and the fractional parts of OSB were in parallel direction according to the work by Pimentel (2009). All processed material remained, before the bonding process, in a conditioned room (65% RH;20°C) until they reached equilibrium weight. As recommended, the material was dried to 12% moisture content and the apparent density was calculated according to standard COPANT 30:1005 / 461 (1972).

The adhesives used were resorcinol formaldehyde (labeled as RF) and castor oil-based polyurethane (labeled as PU) following the manufacturer's recommendations: 350g/m² adhesive spread with a brush. The wood pieces were glued individually with MDF and OSB pieces and pressed for 24 hours at 1 N/mm² constant real pressure.

After adhesive curing period, the glued material stayed in a conditioned room until they reached equilibrium weight. 144 samples were prepared according to ASTM D-905 (ASTM, 1994), divided into 12 different treatments with 12 repetition each, as shown Table 1.

TABLE 1

### 2.2. Mechanical tests

First it was found the breaking load for the subsequent calculation of the glue-line shear strength according ASTM D905-03 (2005) standard. The tests, parallel to the glue line, were performed at the Physics and Engineering Wood Laboratory (LPF-SFB).

### 2.3. Percentage of wood failure

The percentage of wood failure, calculated according to standard D5266-99 (ASTM, 2000). In this technique, it was used a network of squares drawn on a transparent material. The analysis was performed with the aid of a graph paper (50 x 50 mm), and being possible to count the spaces, consider the percentage of area in the glue line sheared and sheared in the wood itself.

### 2.4. Statistic analysis

Data were subjected to an examination of outliers and a completely randomized design to evaluate the effect of wood species, panels and adhesives. The mechanical test results were interpreted with the assistance of an ANOVA and Tukey HSD test at 5% significance (95% confidence interval).

## 3. Results and Discussion

The averages of the glue line shear strength for each treatment are shown in table 2. Three different groups were classified ("a", "b" and "c"), being the highest values for treatment 11.

TABLE 2

When evaluating only the effect of species (Figure 1), two significantly different groups ("a" and "b") were found. The bonding between CM and AM, independent panel and the adhesive used presented smaller values of the glue line shear strength whereas CD showed a higher value. This result can be explained by the low density of CD, 0.51 g/cm ³, it means a more porous and permeable wood, thus allowing better penetration of the glue, causing more effective glue line (BRADY and KAMKE, 1988). No starved glue line was observed.

CM wood presents a high content of silica ($SiO_2$). The extractives migrate to the surface during bonding so the adhesive penetration decreases because of high surface tension (SERNEK *et al*, 2004). For AM wood, the presence of tyloses and brown unknown substance in the tanninfer tubes (RICHTER and DALLWITZ, 2000) cause the same effect.

FIGURE 1

When evaluating the isolated effect of the adhesives, the results for glue line shear strength were not significantly different (Figure 2). The PU adhesive presented higher value, independent of the species and panel used, corroborating the results founded by Pimentel (2009). The presence of additives influences the penetration of the adhesive (KAMKE and LEE, 2007).Therefore, it should be highlighted that castor oil is present in the formulation of PU adhesive, which can make it less sticky and easy to penetrate. The RF values were smaller; the spread rate used in this work recommended by the manufacturer may have influenced this result. Santos (2010) indicates that there is an optimal spread rate for each interface. Depending on the density of the wood, this rate can be less than that recommended by the manufacturer.

FIGURE 2

According to Figure 2, the isolated effect of the type of panel was analyzed. The value found for the OSB was statistically different and greater than that value found for the MDF. OSB has a higher shear strength than plywood in general (COELHO & GUILHERME, 2010) and has discontinuous glue line, which favors the penetration of the adhesive. While the MDF, with a continuous glue line, has its dimensional stability affected by the size of its fibers, smaller than the strands of OSB, and has high resin content. However, the values of glue line shear strength with OSB are lower when compared with the values reported by Pimentel (2009). This author found an average value of 3.36 N/mm² for the tropical woods, seru (*Allantoma lineata*), marupá (*Simarouba amara*) and louro-vermelho (*Sextonia rubra*). Thus, we can infer that it is possible to achieve higher values when bonding hardwood with OSB.

### 3.1. Percentage of wood failure

The percentage of wood failure found for the 12 treatments are in table 3. It can be inferred that a lower percentage of wood failure is related to a higher efficiency of the adhesive. The results show that the percentage of wood failure is quite low in some treatments, and zero in others. It indicates that the rupture occurred most often in the panels, neither in the timber nor in the glue line. This situation provides reliability to the bonding and can be justified by the lower strength of panels to the rupture when compared to solid wood (Figure 3).

TABLE 3.

FIGURE 3

The combination of wood with MDF generates little failure in the wood. This way, the rupture was more often in the panel instead of wood, probably because its lower shear strength. This result leads the indication of the OSB for the I-beams webs to bear a higher load (LEICHT *et al*, 1990). Santos (2008) studied the bonding of OSB with LVL and found glue line shear strength of 3.0 N/mm², which provides these materials are suitable for I-beam manufacturing.

## 4. Conclusions

- The glue line shear strength between wood, MDF and OSB, is influenced by the species, the type of adhesive and the type of panel.
- The *Cedrelinga catenaeformis* wood showed higher glue line shear strength, independently of panel and the adhesive used.
- Castor oil-based polyurethane showed higher glue line shear strength; between panels OSB presented the highest strength;
- For I-beams manufacturing it is recommend the utilization of *Cedrelinga catenaeformis* wood, castor oil-based polyurethane and OSB panel, this leading to bear the highest rupture load.

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**Table 1:** Experimental design (Where: CM = Castanha-de-Macaco Wood - *Carinianamicrantha*; CD = Cedroarana Wood - *Cedrelingacatenaeformis*; AM = AmapáWood - *Brosimumparinarioides*; RF = resorcinol-formaldehyde; PU = castor oil-based polyurethane).

| Species | Adhesive | Panel | Treatments | Number of |
| --- | --- | --- | --- | --- |

| | | | | Samples |
|---|---|---|---|---|
| CM | RF | OSB | **T1** | 12 |
| | | MDF | **T2** | 12 |
| | PU | OSB | **T3** | 12 |
| | | MDF | **T4** | 12 |
| CD | RF | OSB | **T5** | 12 |
| | | MDF | **T6** | 12 |
| | PU | OSB | **T7** | 12 |
| | | MDF | **T8** | 12 |
| AM | RF | OSB | **T9** | 12 |
| | | MDF | **T10** | 12 |
| | PU | OSB | **T11** | 12 |
| | | MDF | **T12** | 12 |

**Table 2:** Mean values of the glue line shear strengt for the different evaluated treatments. (Note: In each row, means followed by same letter do not differ statistically by Tukey test at 5% significance)

| **Treatment** | $f_{gv,0}$ (N/mm$^2$) |
|---|---|
| T10 | $1,44_{a}$ |
| T2 | $1,65_{a}$ |
| T12 | $1,65_{a}$ |
| T5 | $2,43_{b}$ |
| T3 | $2,44_{b}$ |
| T1 | $2,51_{b}$ |
| T8 | $2,52_{b}$ |
| T6 | $2,54_{bc}$ |
| T4 | $2,64_{bc}$ |
| T9 | $2,95_{bc}$ |
| T7 | $3,03_{bc}$ |
| T11 | $3,18_{c}$ |
| T10 | $1,44_{a}$ |

(Where: T1 = CM/OSB/RS; T2 = CM/MDF/RS; T3 = CM/OSB/PU; T4 = CM/MDF/PU; T5 = CD/OSB/RS; T6 = CD/MDF/RS; T7 = CD/OSB/PU; T8 = CD/MDF/PU; T9 = AM/OSB/RS; T10 = AM/MDF/RS; T11 = AM/OSB/PU; T12 = AM/MDF/PU).

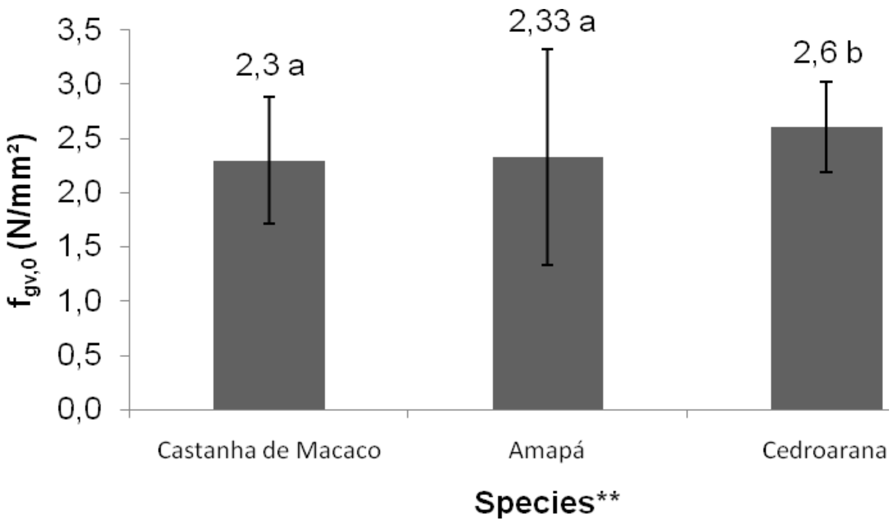


**Figure 1**–Effect of species on the tensile strength. (** Means followed by same letter do not differ statistically by Tukey test at 1% significance).

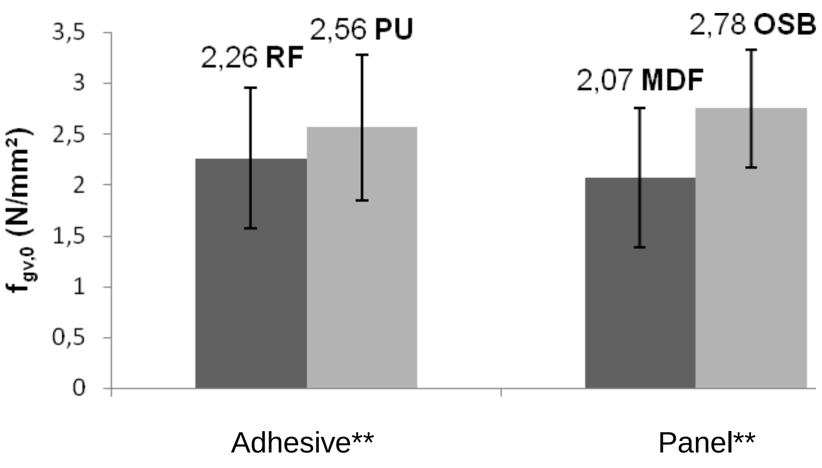

**Figure2** –Effect of adhesives and panels in the glue line shear strength.
(** Means followed by same letter do not differ statistically by Tukey test at 1% significance).

**Table 3** - Percentage of wood failure for the different treatments.

| **Treatment** | % |
|---|---|
| T10 | 0,00 |
| T12 | 0,00 |
| T2 | 0,00 |
| T5 | 0,00 |
| T6 | 0,00 |
| T8 | 0,00 |
| T9 | 0,00 |
| T1 | 0,17 |
| T11 | 0,53 |
| T7 | 0,85 |

| | |
|---|---|
| T4 | 11,19 |
| T3 | 12,25 |
| T10 | 0,00 |

**Figure 3** – Inner surface aspect of the samples - Failure on OSB panel (left) and failure on MDF panel (right).

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