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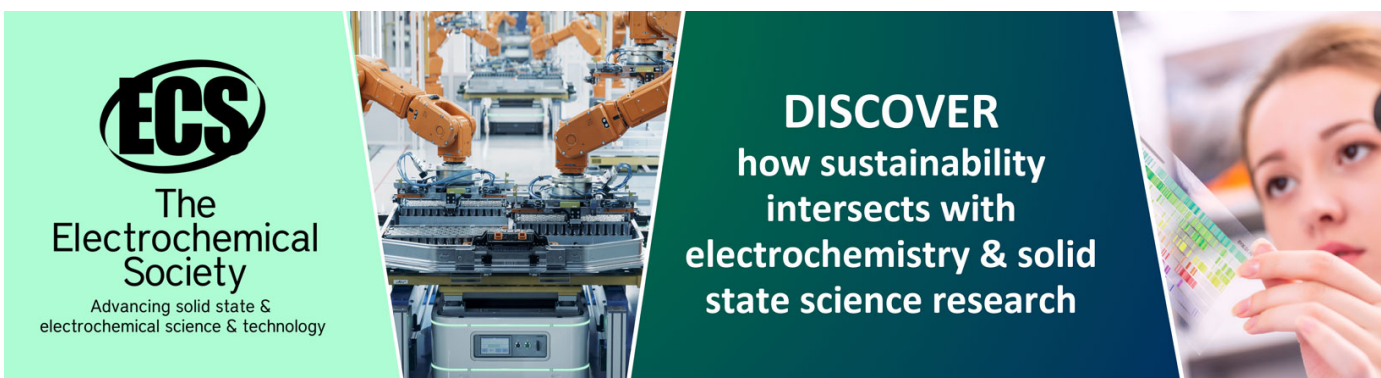
## Optimization of the bamboo *guadua angustifolia* kunth in the elaboration of glued laminated elements for constructive use

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# Optimization of the bamboo *guadua angustifolia kunth* in the elaboration of glued laminated elements for constructive use

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**Abstract.** Bamboo is considered one of the best timber resources in the world because for its mechanical properties and high sustainability; this research aims to improve the mechanical properties of the laminated glued bamboo *Guadua Angustifolia Kunth* (GAK) for use as structural elements, starting from the very manufacture process; this is important because it is possible to observe variations in the flexural strength and the elastic modulus in GAK samples taken from different heights and thickness of the culm.

In order to analyze the influence of these final mechanical properties variations in the laminated, the height of the culm where samples are extracted (cepa, basa and sobrebasa) it is taken as a variable from where different types of laminated were manufactured, seeking to make optimal the configuration based in the transversal section area and the material strength.

Three assemblies were designed varying the overlap of the adhesion lines and it concluded that the highest strength average values were obtained in the laminated composites manufactured with samples taken from the bottom of the culm (basa), which is possible because in these elements there are less adhesion lines than the other ones (middle, top and mixed) or the better matching of themselves.

## 1. Introduction

The bamboo - *Guadua* is considered one of the wooden species with the best physical-mechanical properties and high sustainability. In addition, is known like one of the biggest bamboos of the world, in which it is possible to find 30 meters of highness and 22 centimetres of diameter figure 1 [1].

The transversal section of *Guadua Angustifolia Kunth* (GAK) presents differences in the radial direction, where the parenchyma cells, vascular bundles and fibres are located.

The fibre concentration varies according the height of the stem and in the radial direction from the outer to the inner diameter. As a result, the mechanical properties of the GAK vary significantly according to the height section and the thickness of the specimen [2].

This study seeks to improve the mechanical properties of GAK derivative products, specifically the glued laminated composites used for structural applications by analysing the manufacturing process.





**Figure 1.** Bamboo Plant type: *Guadua Angustifolia* Kunth.

## 2. Materials and Methods

To the laminates elaboration, stems 75 cm long were cut off from three different cross section heights (bottom, middle and top); and afterwards, the sheets were extracted and machined in order to conform the glued laminated composites.

At the end, the composites had 40\*40 [mm] on the cross section according to the NTC301 standard (Colombian Technical standard), figure 2 and 3.



**Figure 2.** Initial cuts in the Bamboo GAK.



**Figure 3.** Bamboo GAK glued laminates.

### 2.1. *The structural glued laminated manufacturing process: important aspects*

One of the most important aspects in the elaboration of these composites is the quality of the interfacial or adhesion line, this depends of the surface quality of the raw material and the adhesive selected; about this issue, prior studies have shown that the best adhesive is the based in melamine resin because of his mechanical resistance and durability against humidity, however, in this study it was taken as a research topic only the mechanical behaviour, so a polyvinyl based adhesive was used in this case [3].

Another study aspect is how to achieve an improvement in the use of the raw material, making it more efficient. For the elaboration of the sheets that conforms the laminates near the 30% to 50% of

the total stem it was wasted; however, if the right technologies are proposing, it is possible to reduce that percentages [4].

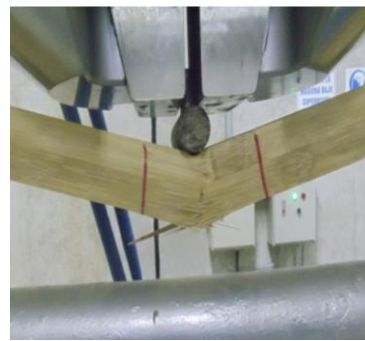
The raw material was obtained from Induguadua S.A., this company has the support of the autonomous regional corporation of Quindío Department (CRQ), who is in charge of grant permissions and environmental licences in this geographical area.

## 2.2. *Mechanic characterization*

The mechanical properties of the laminated composites were obtained by flexural testing according to NTC 663 standard (Colombian technical standard). The equipment used for the test was a Multitest System MTS 50, with a load cell of 500 Kn. The maximum values obtained ranged between 69 and 141 Kg-f/cm<sup>2</sup> (see figure 4).

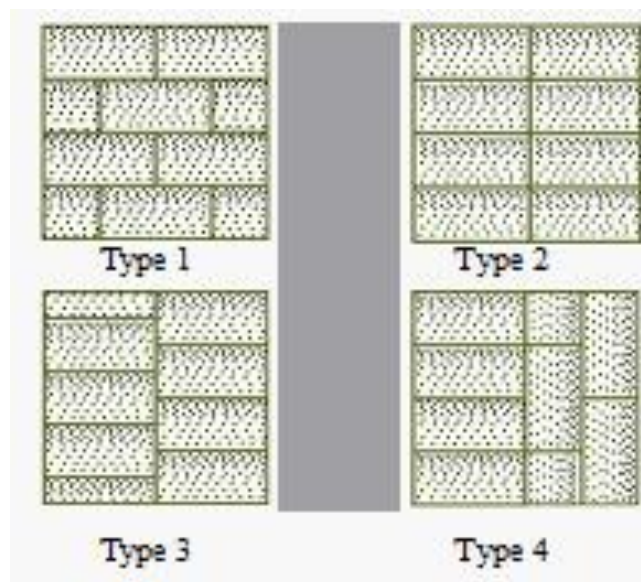


**Figure 4.** Initial cuts in the Bamboo GAK.



**Figure 5.** Bamboo GAK glued laminates.

There was 30 samples tested, manufactured with different types of sheets specimens in order to ensure the independence of the results; the relative humidity was 12% and the stems were mature (between 4 to 6 years) (see figure 5).



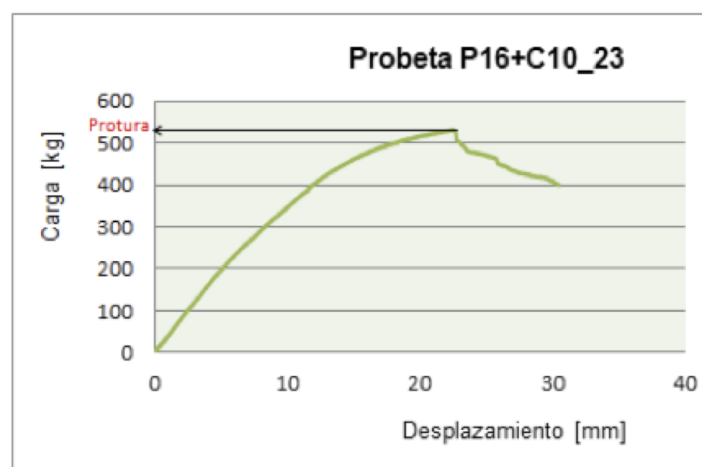
**Figure 6.** Four different types of special orientation sheets for the laminates.

### 3. Results

The composites exhibited densities between 0,743 and 0,731 [g/cm<sup>3</sup>], it was observed that there aren't exist significant differences between the laminates made with bottom sheets (type 1) and the other combinations; the average values of the densities in the combined configuration composites (types 3 and 4) from middle and top sheets was 0,722 [g/cm<sup>3</sup>], close to the densities of middle and top.

The final stress values show that the best configurations were the bottoms sheets based ones, located between 71,4 Mpa end 56,6 Mpa.

The stresses were calculated from the stress-strain diagram, and then it was made a comparison table about the mechanical properties founded, in which it is possible to look that the weight/stiffness relation is favorable if it is compare with others construction materials (see figure 7).



**Figure 7.** Load vs. displacement curve of a laminated type 1 based on bottom sheets sample.

In general, the resistance values of the whole laminates set had a similar mechanical behavior; the difference between each type of laminate configuration was the quantity of adhesion lines required for the manufacturing process.

### 4. Conclusions

In the bamboo glued laminated manufacturing process, the most important issues are the material mechanical properties of the raw material, the sheets geometry and its spatial orientation.

The laminates manufactured with bottom sheets showed the best mechanical properties in the flexural stresses, with maximum values 54 kg-f/cm<sup>2</sup>.

The sheets with the biggest fibers concentration are the middle and top ones, however the laminates with the best mechanical behavior were the composites made with bottom sheets (type 1), this it is possible perhaps this type of laminates need less raw material and therefore less adhesion lines.

### Acknowledgements

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