Key Engineering Materials Vol. 600 (2014) pp 57-68
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doi:10.4028/www.scientific.net/KEM.600.57

Mechanical Behavior of Glued Laminated Pressed Bamboo Guadua using Different Adhesives and Environmental Conditions

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Keywords: Guadua angustifolia, laminated bamboo, aggressive environmental conditions, delamination, mechanical properties.

Abstract. This paper presents the mechanical properties measured on glued laminated pressed guadua samples. Experimental tests like shear parallel to fiber, tensile and shear perpendicular to fiber and flexural tests were carried out using three different types of adhesives: European Melamine Urea Formaldehyde, Colombian Melamine Urea Formaldehyde, and Polivinil Acetate humidity resistant. In order to study the behavior of the material in aggressive environmental conditions, half of the samples used in the mechanical tests were introduced in a temperature and humidity chamber for 45 days set to 45°C of temperature and 95% of relative humidity, usual environmental conditions in Chocó – Colombia.
The results showed that the highest values of mechanical strength were obtained for samples made with European Melamine Urea Formaldehyde. In addition, it was found that this adhesive was the one with better behavior under the aggressive environmental conditions simulated.

Introduction

Traditionally in Colombia, the bamboo *Guadua angustifolia* has been used as a construction material in the raw form; its variable tubular section makes difficult the assembly of structural elements and the standardization of the construction processes. Thus, the Glued Laminated Pressed Bamboo Guadua (GLPBG) arises as a sustainable construction material that has an adequate mechanical behavior, it is manufactured with a standard transversal section that makes easier its industrialization as construction material.

In Colombia, different researches have been carried out aimed to know the mechanical behavior of GLPBG. Preliminary studies made by Barreto [1] and López & Correal [2] showed that the GLPBG has an adequate structural behavior as a structural material. Later on, some research made using this material has been aimed to establish its mechanical properties for different loads and for different conditions of manufacture. In this way, Cortés et al. [3] investigated the influence of the adhesive in the mechanical behavior of the material; Correal & Ramirez [4] evaluated the influence of the type and quantity of adhesive in the behavior of the shear on glue line and static bending; Correal et al [5] found out experimentally the mechanical and physical properties of the material; Varela et al. [6] made a preliminary study of sheathing-to-framing connections; Alvarado et al [7] carried out tests to study the compression behavior of columns with rectangular solid and box cross section; Hackmayer et al [8] made a research aimed to study experimentally the bending behavior of beams with rectangular solid and box cross section; Gonzalez et al [9] studied the structural behavior of the material under perpendicular and parallel plane loads; Luna & Takeuchi [10] studied experimentally the behavior of frames made with GLPBG under lateral load for two types of bracing: type K and panels.

The objective of this research is to study the mechanical and delamination behavior of GLPBG in aggressive environmental conditions using three types of adhesives during its manufacture: European Melamine Urea Formaldehyde (EMUF), Colombian Melamine Urea Formaldehyde (CMUF), and Polivinil Acetate humidity resistant (PVA).

The EMUF is a thermoset resin, fabricated by Casco Adhesives AB and distributed in Colombia by Interquim S.A; is a Melamine Urea Formaldehyde glue type 1242 (composed by ethanediol 1-3, methanol 1-3 and formaldehyde 0,1-1), with a hardener 2542; the components density of EMUF are 1250 kg/m^3 for 1242 and 1300 kg/m^3 for hardener 2542. In the same way, CMUF is a thermoset resin distributed in Colombia by Interquim S.A; is the mixture of the polymer 216 FE-L (produced by condensation of urea with melamine), polymer 103 and hardener CFM 40. On the other hand, PVA is a thermoplastic resin, obtained by polymerization of vinyl acetate monomer, with 1009 kg/m^3 of density.

Materials and production process

All the slats used for fabricate the samples for the experimental program were acquired from a bamboo small industry. The pressing process and fabrication of tests samples were performed in the Universidad Nacional de Colombia (National University of Colombia); the pressing pressured used was 7 kg/cm². The first step in the production process consist in the conformation of elements with dimensions 5cm x 5cm x 200cm (height x width x length); next were cut all the samples for mechanical tests.

In order to study the influence of different adhesives in the mechanical and delamination behavior of GLPBG in aggressive environmental conditions were manufactured samples with EMUF, CMUF and PVA.

Experimental program

In order to study the behavior of the GLPBG in aggressive environmental conditions, the experimental program of this research was performed in two phases: the first phase consisted on mechanical tests in samples that were not introduced in a temperature and humidity chamber; the second phase consisted on mechanical tests in samples after they were introduced in a temperature and humidity chamber for 45 days with 45°C of temperature and 95% of humidity, usual environmental conditions in Chocó – Colombia.

Tests of shear parallel to fiber, tensile and shear perpendicular to fiber and bending tests were carried out on samples fabricated and tested according to the procedures of the Colombian Technical standards (Normas Técnicas Colombianas, NTC)

Bending tests. 60 samples were made using the procedures established on NTC663 [11]; 20 samples were glued using EMUF, and the same number with CMUF and PVA. Fig. 1 – Dimensions used on bending test

shows the dimensions used.

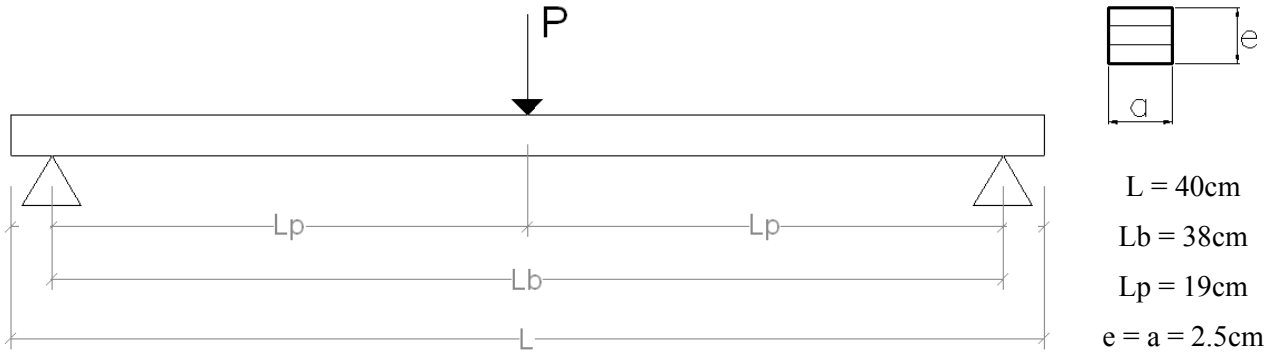


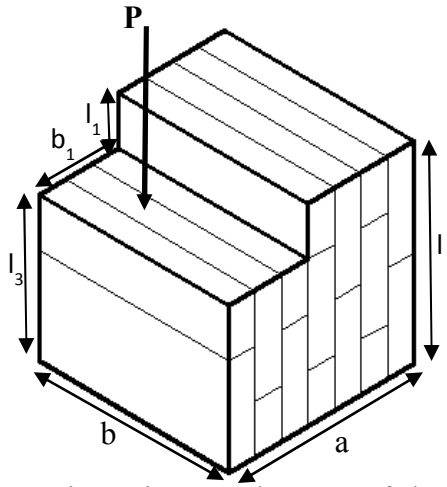
Fig. 1 – Dimensions used on bending test

Half of samples for each adhesive were introduced in the temperature and humidity chamber before the mechanical test and the other half were not introduced. In order to study the influence of slats position in the flexural behavior, half of samples were tested with slats in vertical position and the other half with slats in horizontal position. Fig. 2 presents a photograph of test setup and the typical failure of tested samples.

(a) (b)

Fig. 2 – Bending test: (a) Before mechanical test; (b) Typical failure

Tests of shear parallel to glue line. 60 samples were fabricated using the procedures established on NTC775 [12]; 20 samples were glued using EMUF, and the same number with CMUF and PVA. Half of samples for each adhesive were not introduced in temperature and humidity chamber before the mechanical test and the other half were introduced. Fig. 3 shows the dimensions used, and Fig. 4 a photograph of test setup and the typical failure of tested samples.



$l = 5cm$

$l_1 = 1.5cm$

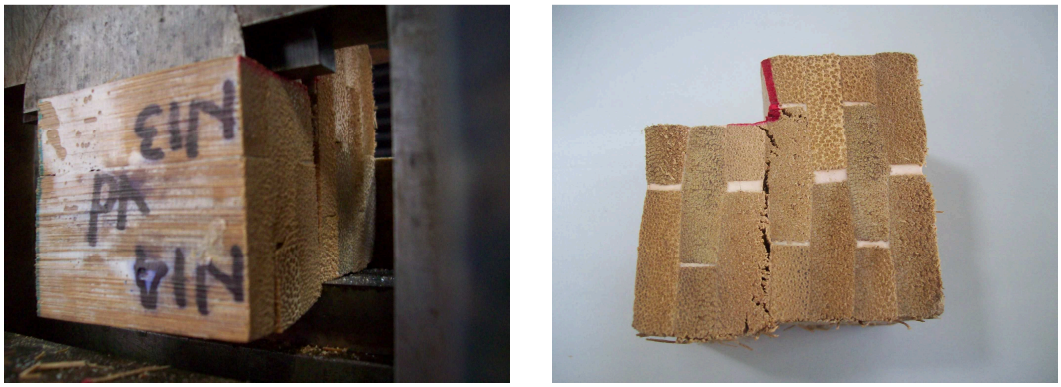
$l_3 = 3.5cm$

$a = 5cm$

$b = 5cm$

$b_1 = 2.5cm$

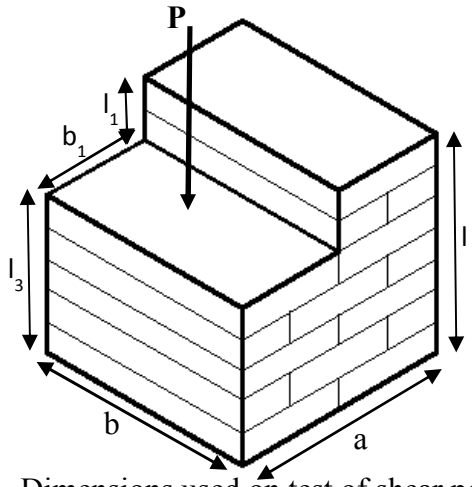
Fig. 3 – Dimensions used on test of shear parallel to glue line



(a) (b)

Fig. 4 – Test of shear parallel to glue line: (a) Before mechanical test; (b) Typical failure

Tests of shear perpendicular to glue line. 60 samples were fabricated samples using the recommendations on Cortés's [3] research; 20 samples were glued using EMUF, and the same number with CMUF and PVA. Half of samples were not introduced in temperature and humidity chamber before the mechanical test and the other half were introduced. Fig. 5 shows the dimensions used, and Fig. 6 a photograph of the typical failure of tested samples.

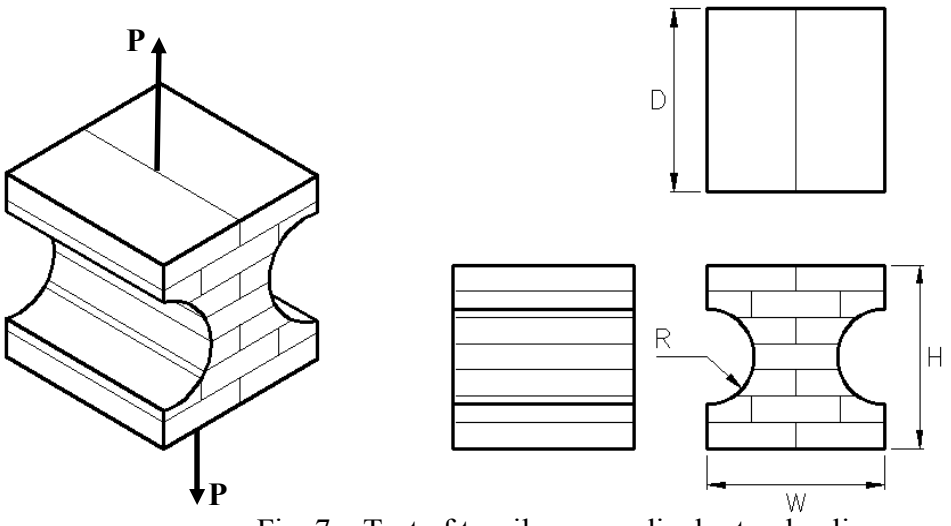


l = 5cm
l_1 = 1.5cm
l_3 = 3.5cm
a = 5cm
b = 5cm
b_1 = 2.5cm

Fig. 5 – Dimensions used on test of shear perpendicular to glue line

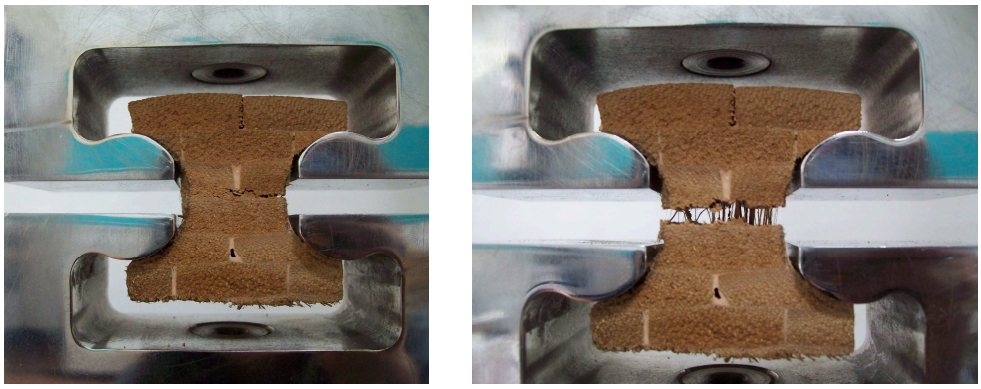
Fig. 6 – Typical failure of tested samples

Test of tensile perpendicular to glue line. 60 samples were fabricated samples using the procedures established on NTC961 [13], with the glue line perpendicular to the application load direction; 20 samples were glued using EMUF, and the same number with CMUF and PVA. Half of samples were not introduced in temperature and humidity chamber before the mechanical test and the other half were introduced. Fig. 7 shows the dimensions used, and Fig. 8 a photograph of test setup and the typical failure of tested samples.



D = 5cm
W = 5cm
H = 5cm
R = 1.3cm

Fig. 7 – Test of tensile perpendicular to glue line



(a) (b)

Fig. 8 – Test of tensile perpendicular to glue line: (a) Before mechanical test; (b) Typical failure

Test of tensile parallel to glue line. 60 samples were fabricated samples using the procedures established on NTC961 [13], with the glue line parallel to the application load direction; 20 samples were glued using EMUF, and the same number with CMUF and PVA. Half of samples were not introduced in temperature and humidity chamber before the mechanical test and the other half were introduced. Fig. 9 shows the dimensions used, and Fig. 10 a photograph of test setup and the typical failure of tested samples.

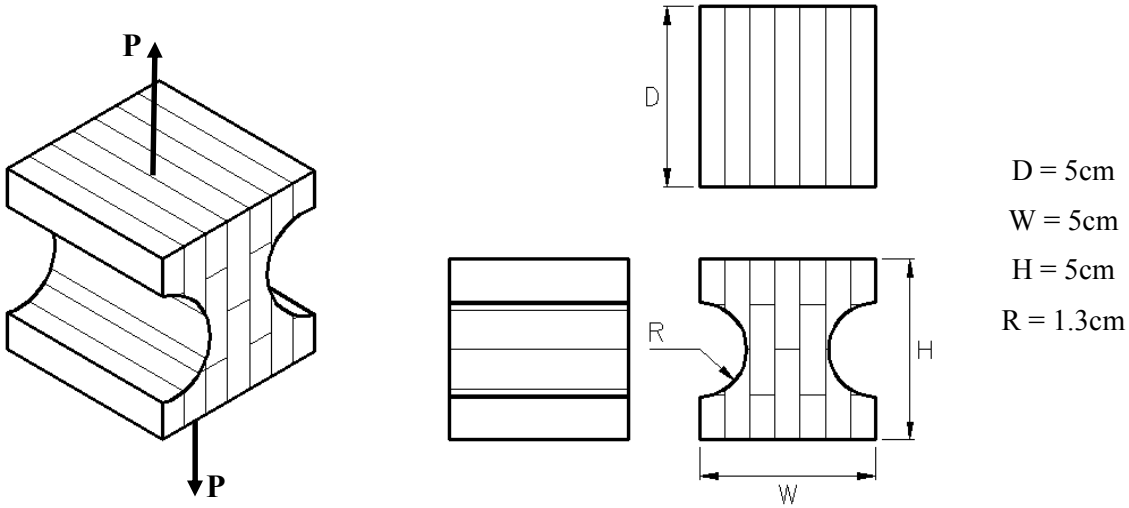
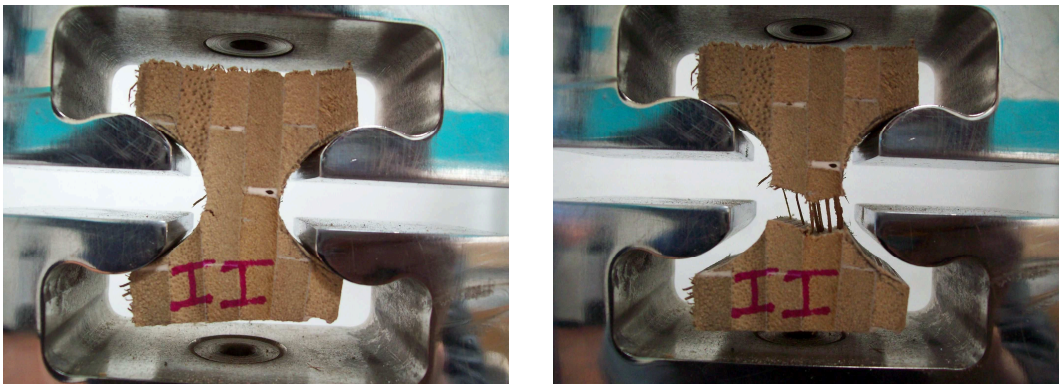


Fig. 9 – Test of tensile parallel to glue line test



(a) (b)

Fig. 10 – Test of tensile parallel to glue line: (a) Before mechanical test; (b) Typical failure