Key Engineering Materials Vol. 517 (2012) pp 184-188
Online available since 2012/Jun/26 at www.scientific.net

doi:10.4028/www.scientific.net/KEM.517.184

Experimental Analysis of Frames Made with Glued Laminated Pressed Bamboo Guadua

Patricia Luna[1,a *], Caori Takeuchi[2,b]

[1]Carrera 30 #45-03 Edificio 304 Instituto de Investigaciones Tecnológicas, Bogotá – Colombia

[2]Carrera 30 #45-03 Edificio 406 Oficina 301, Bogotá – Colombia

[a]plunat@unal.edu.co, [b]cptakeuchit@unal.edu.co

Keywords: Bamboo Guadua, laminates, frames, ultimate load, cyclic load

Abstract. This article presents the experimental tests results of frames made with glued laminated pressed bamboo guadua under lateral load. The tested frames had two floors with 1.40m of height each one and 2.80m of total height; the width of the frames was 2.10m. Beams and columns had square box cross-section of 0.10m side and 0.015m of wall. Three frames had bracing type K and other threes had panels. The adhesive used for the manufacture of beams, columns and braces was Urea Melamine Formaldehyde and for the elaboration of panels was Polyvinyl Acetate. The frames of glued laminated pressed bamboo guadua had elastoplastic behavior with great ductility.

Introduction

In Colombia bamboo *Guadua Angustifolia* has been used as structural material since pre-Columbian era; its use is as raw guadua that has variable tubular section which makes it difficult to assemble different elements of the structure and also to standardize construction processes. That is how the glued laminated pressed bamboo guadua is an alternative construction material with adequate mechanical properties and the environmental benefits of bamboo Guadua Angustifolia and with the advantages of an industrialized product which encourages the demand for this material.

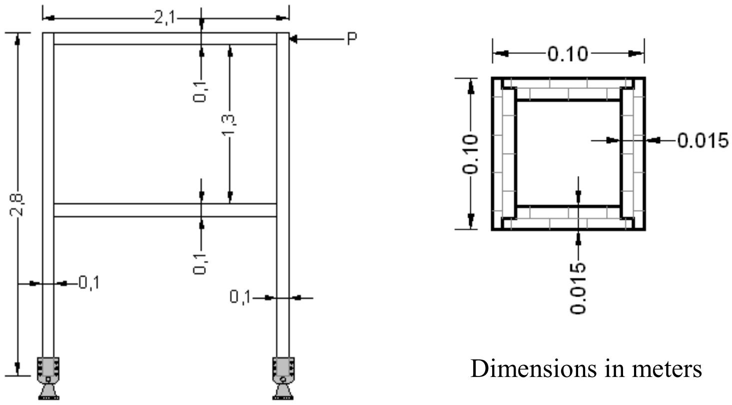
Currently, the National University of Colombia (*Universidad Nacional de Colombia*) is developing the research project "Design and construction of housing with structural elements made with glued laminated pressed Guadua" financed by the Ministry of Agriculture and Rural development of Colombia (*Ministerio de Agricultura y Desarrollo Rural de Colombia*), which consists in the manufacture and testing of specimens and structural elements as beams, columns, panels, floor boards and frames made of laminated bamboo guadua. The principal objective of the project is encourage the use of bamboo guadua as industrialized construction material, which has adequate mechanical behavior to different loads.

One of the first studies carried out aimed to understand the mechanical behavior of the material was developed by Gonzalez et al [1];. they studied the behavior to the shear test of beams laminated of guadua *Angustifolia Kunth* with three different adhesives; likewise, Gonzalez et al [2] studied the bending behavior of beams for two different rectangular cross section and double T cross section. Lopez [3] made an exploratory study on the structural potential of laminates in guadua; Cortes [4] carried out parallel and perpendicular shear and compression, perpendicular tensile and bending tests to evaluate the behavior of glued laminated guadua using four types of adhesives. Estrada [5] investigated the possibilities of design and construction of structural elements of laminated guadua; Varela [6] studied experimentally the behavior of panels made with laminated guadua used as shear walls; Quiroga [7] studied the influence of nodes and finger joins in laminated guadua, Atoche [8] evaluated the structural behavior of joins between laminates that make up the element of laminated guadua; Luna et al [9] carried out tests to study the compression behavior of columns for two types of cross section. Pinilla [10] studied the structural behavior of the material under perpendicular and parallel plane loads. Rodriguez [11] evaluated experimentally the influence of slats density on bending behavior; additionally, this study present tables and design curves for beams with solid and box cross section.

This article presents the experimental results obtained in tests of frames made with glued laminated pressed bamboo guadua under lateral load, for two types of bracing: type K and panels.

Experimental methodology

Were manufactured and tested six two-story frames, each story with 1.30m of height and 2.10m of width. Columns and beams had square box cross-section of 0.10m of side and 0.015m of thickness wall. The material used for the manufacture of elements was glued laminated pressed bamboo guadua that uses Urea Melamine Formaldehyde as adhesive. The general configuration of frames and the cross-section of the elements are shown in Fig. 1.



a) b)

Fig.1. General configuration of frames: a) dimensions, b) cross-section

To assemble beams and columns, steel angles of 3/8" in thickness with three bolts of 3/8" of diameter on each side were used; Fig. 2 presents the join used.

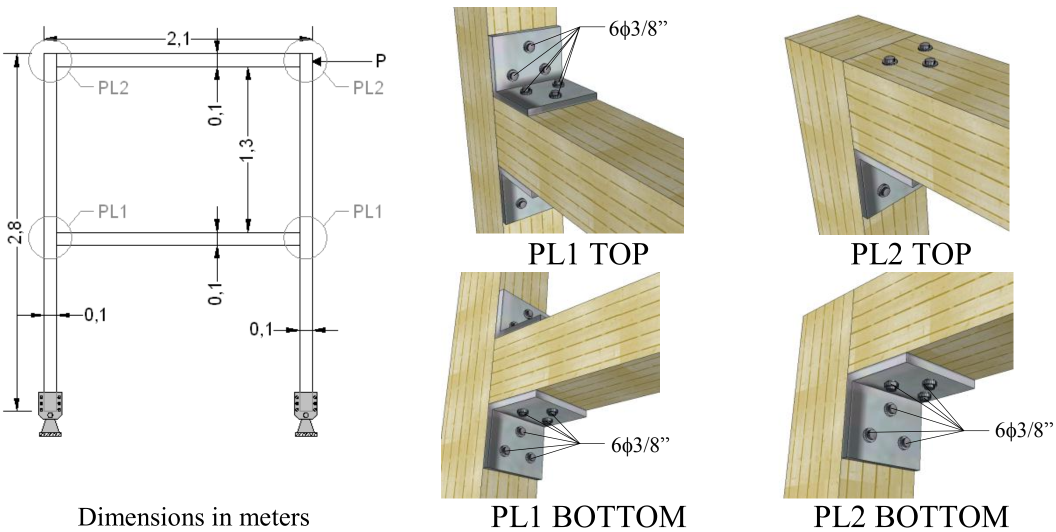


Fig.2. Join between beams and columns

Three frames were stiffened with K-bracings manufactured with laminated bamboo guadua, glued with Urea Melamine Formaldehyde. K-bracings had square solid cross-section of 0.05m of side and were attached to the structure using screws; in order to avoid failure at the connection point, blocks in glued laminated pressed guadua were located to restricting the movement of the bracing when the structure was loaded laterally. Fig. 3 shows this type of structures.

The panels used to brace the remaining structures were made with laminated pressed guadua, glued with Polyvinyl Acetate. For each structure were used 38 panels (19 for each story) with dimension 1.30m X 0.20m X 0.015m (length X width X thickness), which were screwed to each side of a inset attached to the frame. Fig. 4 presents this type of structures.

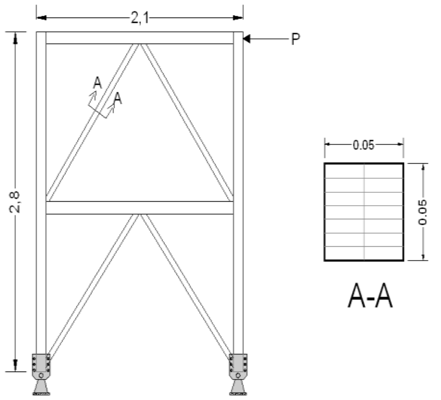


Fig.3. Frames with K-bracing

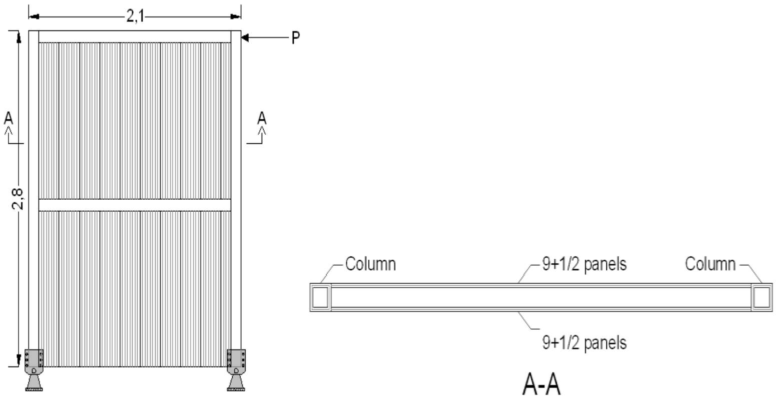


Fig.4. Frames with panels

Physical characterization. Due the variability in the moisture content of the slats used for the manufacture of the structural elements can induce differential stresses that affect the quality and mechanical behavior, was determined the moisture content for 267 sheets selected randomly of the total that were used to built the elements. The determination of moisture content was made using the procedure of NTC5525 [12].

Lateral load tests. The tests were made using a dynamic actuator; for all the frames, the pinned support condition was used and the horizontal load was applied in the point indicated in the Fig. 5 which gradually increases at a rate of 0.4mm/s. For each load increase the total displacement was recorded.

Because it was not possible to carry any of the structures to the failure, the tests were finished when the total displacement was greater than 100mm.

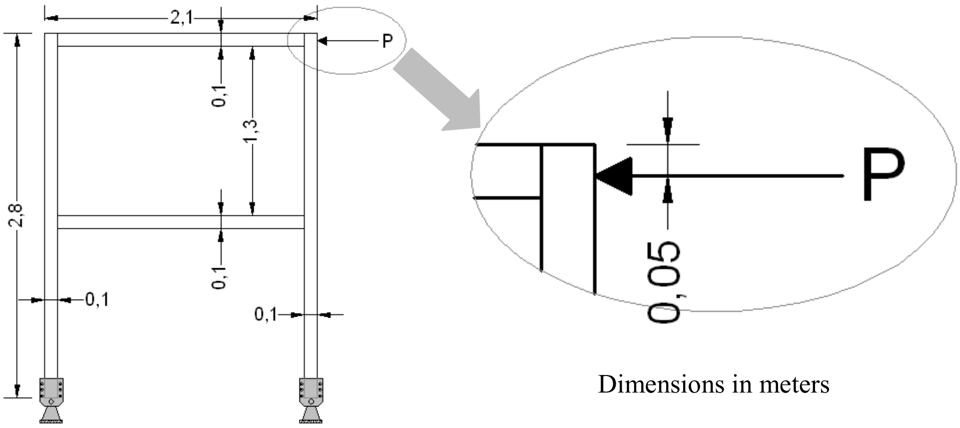


Fig.5. Application point of lateral load

Calculation and results

Moisture content. The average moisture content for the sheets used for the construction of the frames was 11.97%.

Load – displacement curves. Fig. 6 shows the load vs. displacement curves for frames with K-bracing and Fig. 7 for frames with panels.

Test P02TK, shown in Fig. 6, presents an atypical behavior when it is compared with the other two, maybe this situation happened because the screw holding one of the bracing to the base of the frame failed due to defects in its manufacture.

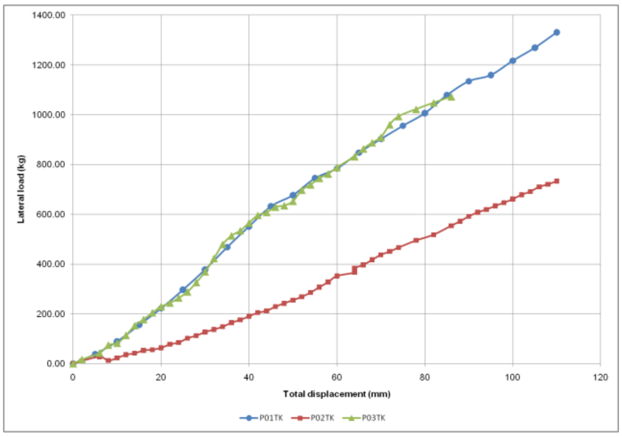


Fig.6. Load vs. displacement for frames with K-bracing

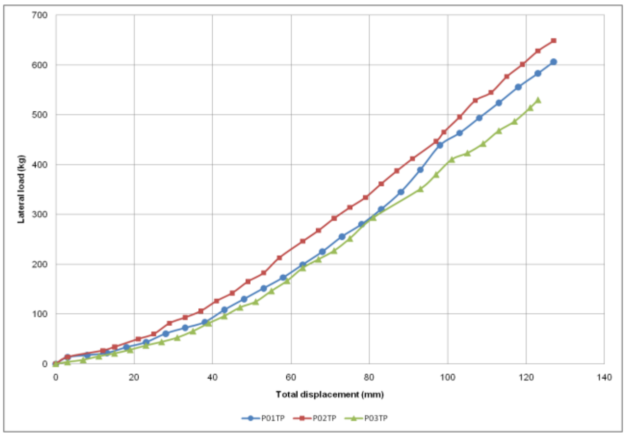


Fig.7. Load vs. displacement for frames with panels

Load – lateral drift curves. Lateral drift for second story was calculated using Eq. 1, where Δ_2 is the lateral drift for second story, δ_1 y δ_2 are the displacements for first and second story, respectively. Fig. 8 shows the load vs. lateral drift for second story curves for frames with K-bracing and Fig. 9 for frames with panels.

$$\Delta_2 = \sqrt{(\delta_2 - \delta_1)^2} \tag{1}$$

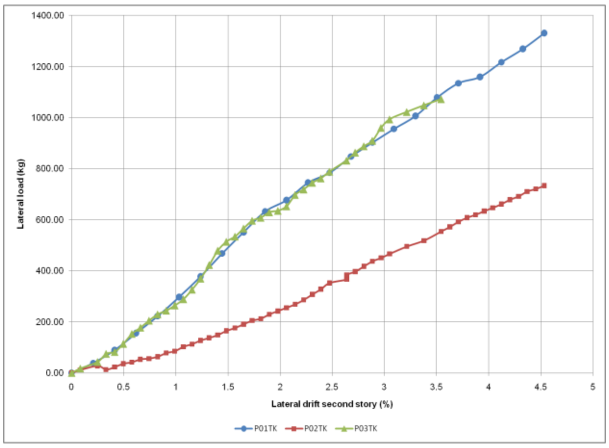


Fig.8. Load vs. lateral drift for second story for frames with K-bracing

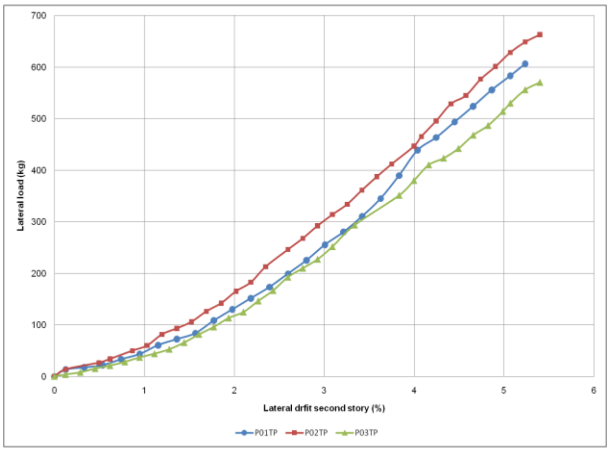


Fig.9. Load vs. lateral drift for second story for frames with panels

Conclusions

Curves of load vs. displacement and load vs. lateral drift for second story for frames stiffened using K-bracing and panels were presented. Load vs. displacement curves show that frames stiffened with K-bracing had an elastoplastic behavior, while the frames stiffened with panels had an elastic behavior with two zones: first stage for accommodation of the structure followed by an elastic region. The results for two types of structures show that the frames had great ductility.

The maximum lateral drift allowed in Colombia by the earthquake resistant building code [13] is the 1%, value for which, the two types of structures tested are still in the elastic behavior area.

Acknowledgements

The authors are grateful for the financial support of the Ministry of Agriculture and Rural Development of Colombia (*Ministerio de Agricultura y Desarrollo Rural de Colombia*), and appreciate the support of CorpoIbama, the Cundinamarca Governor (*Gobernación de Cundinamarca*), the municipality of Pacho and Guaduacol during the various activities of this research.

References

[1] González H. A., Hellwig S, Montoya J.A. Behavior to the shear test of beams laminated of Guadua Angustifolia Kunth. Scientia et Technica Año XIV, No 39. Universidad Tecnológica de Pereira. Septiembre de 2008.

[2] González H. A., Hellwig S, Montoya J.A. Test results of Young's modulus and Resistance to bending of Guadua angustifolia KUNTH laminated. Scientia et Technica Año XIV, No 40. Universidad Tecnológica de Pereira. Diciembre de 2008.

[3] López, L.F. Estudio exploratorio del potencial estructural de laminados de guadua. Tesis de Maestría. Bogotá. Departamento de Ingeniería Civil y Ambiental, Facultad de Ingeniería, Universidad de los Andes; 2008.

[4] Cortés J.C. Evaluación de la influencia del tipo de pegante en el comportamiento mecánico de guadua laminada prensada. Trabajo final de Especialización en Estructuras. Universidad Nacional de Colombia. 2009.

[5] Estrada M. Exploración del diseño y construcción de elementos estructurales de guadua laminada. Trabajo de grado. Universidad de los Andes. 2009.

[6] Varela, S. Estudio Experimental de Paneles de Guadua Laminada Para Uso en Muros de Corte. Proyecto de grado. Bogotá. Departamento de Ingeniería Civil y Ambiental, Facultad de Ingeniería, Universidad de los Andes; 2009.

[7] Quiroga R. Influencia de Nodos y Uniones Dentadas en Laminados de Guadua Angustifolia Kunth. Proyecto de grado. Bogotá. Departamento de Ingeniería Civil y Ambiental, Facultad de Ingeniería, Universidad de los Andes; 2009.

[8] Atoche J.C. Evaluación del comportamiento estructural de conexiones de guadua laminada. Tesis de Maestría. Bogotá. Departamento de Ingeniería Civil y Ambiental, Facultad de Ingeniería, Universidad de los Andes; 2009.

[9] Luna P., Moreno I., Alvarado C., Takeuchi C. Diseño de columnas en guadua laminada prensada pegada. Primer Simposio de bambú y madera laminada. Bogotá, Colombia. 2010.

[10] Pinilla J.J. Comportamiento estructural de guadua angustifolia laminada, ante carga perpendicular y paralela a su plano. Trabajo de grado Maestría en estructuras. Universidad Nacional de Colombia. 2011.

[11] Rodríguez, N. Elaboración de tablas y gráficos de diseño a flexión de vigas de bambú guadua laminada pegada prensada. Trabajo de grado Maestría en estructuras. Universidad Nacional de Colombia. 2011.

[12] Instituto Colombiano de Normas Técnicas. Métodos de ensayo para determinar las propiedades físicas y mecánicas de la Guadua angustifolia Kunth. Bogotá: ICONTEC, 2007 (NTC5525).

[13] Asociación Colombiana de Ingeniería Sísmica. Normas Colombianas de Diseño y Construcción Sismo Resistente. Bogotá: AIS, 2010 (NSR-10).