International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Microscopic Analysis of Bamboo Pieces and Its Relation to Compression Resistance

Sánchez-Medrano, M.T. Suárez-Domínguez, E.J.

Abstract: ***Bamboo has been identified as a structural element capable of satisfactorily absorbing tension and compression stresses, and, to a lesser proportion, parallel shear along its fibers, as well as bending with possibility of usage in buildings and as viable ecological alternative. The ultrastructure of the bamboo, from the Guadua Velutina species, obtained from the Vega Rica ejido in El Higo, Veracruz, Mexico, was characterized It was characterized the ultra structure of the bamboo, of the species Guadua velutina, obtained of the Ejido Vega Rica of the municipality El Higo, Veracruz, Mexico for use in the industry of the construction. Previously, pieces were tested to determine their mechanical properties: compression and shear parallel to the fiber, following the standards indicated in the methodology. Subsequently, the microscopic analysis of longitudinal and transverse sections of this anisotropic material, with variable porosity in its walls, was carried out. It was found that the arrangement and shape of its fibers that give rise to its porosity is correlated with its resistance to the different stresses to which it is subjected and that its porosity also decreases in joints zones, where its fibers have no defined direction. These findings are important because they make it possible to recognize the durability of the material in such a way that they can be considered in the construction of structural elements.***

Keywords: Bamboo microscopy, bamboo's resistance, fiber fractality.

I. INTRODUCTION

The bamboo, a grass that grows in tropical zones, is of a low economical and energy cost of extraction and production, of fast growth if compared to wood, and that has seen usage in Mexico especially in rural construction with favorable results as proven by tradition. The investigation about this natural resource in Mexico, has primarily focused on guaduas, like the one that relates the geometrical characteristics of test tubes with its response to static flexion [1]; as well to determine its mechanic properties [2]-[3]; studies about the anatomy of the walls of the stems of bamboos native to Mexico [4] and about thermic conductivity of bamboo [5]. These studies, which still are scarce, have allowed evaluating bamboo for consideration as an alternative structural material, with important technological applications, not only in rural housing, but also for diverse buildings. Mexico, being in possession of native species of the Guaduas family, as the velutina, amplexifolia, aculeata, among others, must take advantage of this potential, for this, bamboo should be studied by diverse disciplines that provide enough information to take advantage of its benefits and to better or complement its weakness with other materials, as it happens with reinforced concrete, where there are Mexican researches as [6], that model pieces of bamboocrete to revise the possibility of substituting the reinforce iron in elements in flexion.

Countries as Brazil, Colombia, and Peru have more advanced studies about bamboo, perhaps because it exists in larger numbers, actually having norms for its utilization, preservation and drying, for use in connections, between others; which has allowed them to be in the vanguard especially in the development of sustainable and low-cost housing, which is conditional for actual housing.

In this sense, and with the purpose to contribute to the knowledge of bamboo, this research is generated so that it correlates experimental results to the different mechanic efforts of *Guadua velutina* obtained from test protocols established in the Norms [7]-[8], besides a microscopic analysis of the material to correlate this property with its form.

A. Fractal dimension

The patterns that are formed by the solids, such as the ones studied here, are characterized through the fractal dimension of capacity (Γ_c), defined as:

$$\Gamma_c = -\lim_{r\to 0} \frac{\ln N_0(r)}{\ln\left(1/r\right)} \tag{1}$$

where r is the size of the places in which the image is divided into 2D and is the number of places in which the presence of the substance is detected.

The value of the fractal dimension in a system can vary in its dependence on the dynamic processes that take place and from its random nature so that it may describe a system from its morphology. In this research, the morphologies will correspond to the obtained images in regards to previously described experimental phase; the dynamic processes are referred to the interactions between the particles as well as their characteristics, especially their size.

Manuscript published on 30 September 2019
* Correspondence Author
María Teresa Sánchez Medrano*, Facultad de Arquitectura, Diseño y Urbanismo, Universidad Autónoma de Tamaulipas (UAT), CP 89000, Tampico, Tamaulipas, México. Email: tsanchez@docentes.uat.edu.mx
Edgardo Jonathán Suárez Domínguez, Facultad de Arquitectura, Diseño y Urbanismo, Universidad Autónoma de Tamaulipas (UAT), Tampico, Tamaulipas, México. edgardo.suarez@docentes.uat.edu.mx
[1] This project has been supported by CONACYT, under the agreement with the number 2017-5975 and PRODEP, México

This way the observed experimental results will be correlated from its rugosity and fissures respecting to the fractal dimension.

II. METHOD

For the compression and shear parallel to the fiber stresses tests, representative pieces of bamboo from the Guadua velutina species were obtained; attending to the normativity [8]-[9], each test used 12 dried culms between 3 to 4 years old, distributed into strains (low zone near the root), bases (middle zone) and overbases (extreme zone with higher internodal distance), keeping each specimen a 2 to 1 height-diameter relationship. They were submitted for their mechanical and microscopic analysis, and to recognize the effects of porosity, as well as its relationship with the resistance to compression and parallel to the fiber shear stresses.

The surfaces were observed with a *Konus College #5302* microscope, ocular lens *WF 15x,* with a 10X zoom. The patterns were photographed with a SONY DSC-W530 Cyber Shot 14.1 megapixels, a Carl Zeiss lens and optic zooms 4X with a resolution of 7 megapixels.

The fractal dimension was determined through the box-counting method for the chosen patterns through the ImageJ v1.40g software in which each colored image is converted into an 8-bit image, from which a binary image of the pattern is obtained from which the vertical and horizontal fractal dimensions of the images are determined. The have were taken photographs in represent of the longitudinal section and other transverse of the bamboo. In this procedure with a microtome for get sheet of 4 x 4 mm. and 2 mm of thickness, the element of bamboo were metallized with a gold layer that were afterwards with an electronic and scanning with SEM Jeol JSM-6510 LV.

III. RESULTS AND DISCUSSION

Within the results from both of the studied mechanical properties of the Guadua velutina species, showed in Table No.1, it can be observed that for both tests, the higher force was registered in the overbase zone.

Table 1. Average stresses register for the three bamboo culm zones of the species Guaduas velutina. Elaborated by the authors.

SPECIES	*Guadua velutina* (El Higo, Veracruz)	
Compression strength parallel to the fibers		
CULM ZONE	No. of pieces	Avg. Compression Stress MPa
STRAIN	37	27.00
BASE	145	34.37
OVER-BASE	124	40.62
Shear strength parallel to the fiber		
CULM ZONE	No. of pieces	Avg. Parallel cutting Stress MPa
STRAIN	44	3.12
BASE	49	6.35
OVER-BASE	93	6.44

The images taken in the conjunctural sections (nodal) and the central part of the bamboo are observed in Fig. 1.

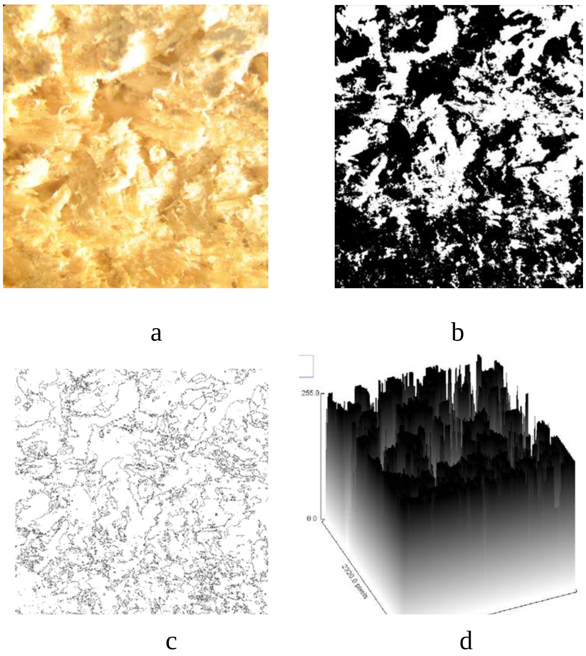

Fig. 1. - Image took to 400 amplifications of a bamboo's surface in the zone of the union. The fractal dimension is 1.85. In a) the original photograph is showed while in b) is black and white in 68 bits, c) is the outlines image and d) is the rugosity's profile. (Own photo)

As expected, low porosity can be distinguished. The Fig. 2 shows the most compact value possible for this zone. When the analysis were realized to compression, a value superior to 40.62 MPa was found. The porosity in volume was 21%. It is possible that this relation comes from the medium's porosity. For example, when the analysis of the mid-section of the bamboo was made, a higher porosity measured by water absorption in 70% in volume was found. Resistance in this section proved to be less than 15%.

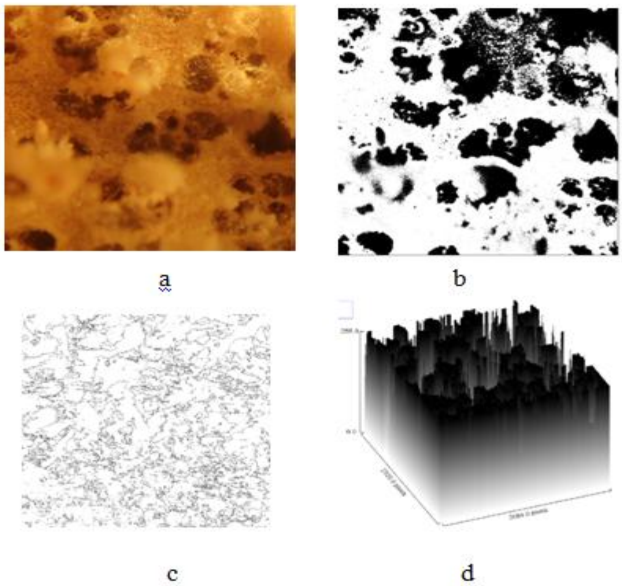

Fig. 2. - Image representative of the central zone of the bamboo.

The fractal dimension was of 1.72. In a) the original photograph is displayed while in b) it is black and white in 68 bits, c) is the outlines image and d) is the rugosity's profile. (Own photo) The analyzed micrographs show the fibers' disposition in the pieces of bamboo. In Fig. 3, when the longitudinal sections is taken, elongated fibers that run along the entire section upon reaching the knot were found. This disposition form seems to present aside from greater resistance to tension because they are intertwined in a net that seems to transmit their stresses in both ways. Although the porous medium in principle it allows to mobilize the plant's sap, once it has been cut, this medium is lost, and it shows a higher tension in the solid. On the other hand, while analyzing the surface, a low porosity was obtained, and in effect, it does not allow the liquid's dispersion.

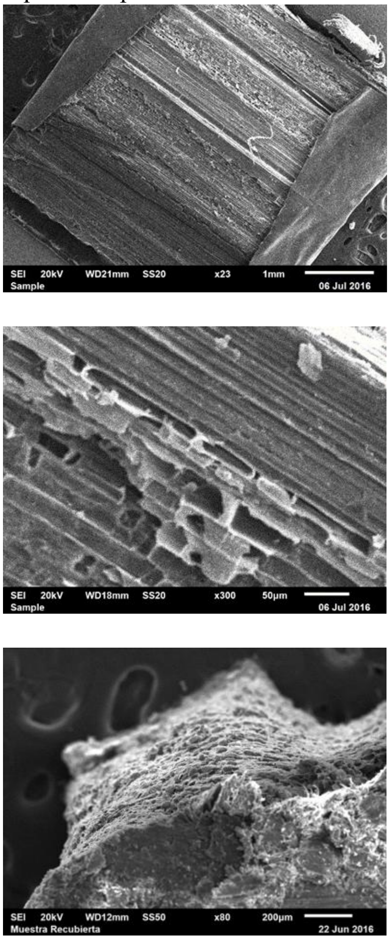

Fig. 3. Surface magnification using a SEM Jeol JSM-6510 LV. (Own photo)

Diverse relations between the spatial structure of the components and some physical properties exist (Xian, Y. et al. 2017) when bamboo has been utilized in composites. The fractal evaluation has even been related in the forms of failure during the material's evaluation (Alves, L. M. et al. 2016).

It should be remarked that this type of evaluations is important because it relates to other properties in fibers such as water absorption [13], which later modifies others such as mechanic resistance to compression, tension and shearing.

While performing the parallel cutting's analysis of the samples, a similar value for the base and over-base is found, but significantly lower for the strain. While analyzing the obtained images from the components, higher compactness is found and so a possible interaction between the fibers, in other words: The cohesion between them is greater which correspond to the results found in this sections where mechanical resistance is greater, simultaneously, this effect is observable in the respective compression too.

It seems the element's compactness is related to a major interaction between the components, visualizing between them a cementing that binds them. On the other hand, a high rugosity is observed that possibly increases interaction when putting through a shearing process. This effect is predominant when said stress is made but even more so, if it is compression, While performing the compression of the element it seems that an increase in resistance exists due to the fibers resisting separation, behaving like joint elements like webbing that reinforce the structure.

IV. CONCLUSION

It was possible to analyze fiber types from micrographic analysis with a Scaning electronic Microscope (SEM). The analyzed species presents different characteristics in the nodule with respect to other sections of it, which was possible to correlate with the porosity and fractal dimension.
Mechanically, when the test was performed to measure compressive strength, resistance was not affected by the presence or absence of joints in the specimens; however, in the shear tests, 15% greater resistance was found in specimens with joints than in those without. That is to say, in the shear stress the joint does intervene in the behavior of the material. These results show that it is possible to use this species in structural elements that could replace the steel in its composition and therefore reduce emissions to the environment.

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AUTHORS PROFILE

María Teresa Sánchez-Medrano, Architecture Ph.D. Teacher-Researcher of the Faculty of Architecture, Design and Urbanism of the Autonomous University of Tamaulipas. It has several publications in of housing technology and alternative materials area. Member of the National System of researchers (SNI) of CONACYT, México

Edgardo Jonathan Suárez-Dominguez, Process administrations Ph.D; PhD Physico-Mathematics; Postgraduate Unit Manager of the Faculty of Architecture, Design and Urbanism of the Autonomous University of Tamaulipas. Teacher-Researcher. It has several publications and patents in the area of mechanical engineering. Member of the National System of researchers (SNI) of CONACYT, México