Physical characterization of two Cameroon bamboo species:Arundinaria alpina and oxytenantera abyssinica

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***Abstract*. Three physical properties (density, porosity and shrinkage) of two Bamboo species from western Cameroon are analysed. The effect of position in a tree (bottom, middle and top) and the growing zone (uphill, valley and slender) of the tree on those physical properties are carrying out. The effect of nodes on physical properties are analysed. Bamboo is a natural composite, constituted of fibres embedded in a lignin matrix in the direction of tree growing. Despite the scattering of the results due to the random distribution of the components, the study shows that the density increase from the bottom to top, the density of the bamboo is more important at the level of the node zone than on the internodes. The outer layer of the culm is more dense than the inner layer, and the uphill bamboo seems to have better physical properties than the valley bamboo.**

Keyword: Uphill, valley , density, porosity, composite, layer

I. Introduction

Bamboo is a fast growing fibrous plant available in abundance on the earth, particularly in tropical and subtropical regions. Their culms can grow to their full height of 3-30m within a few months due to the expansion of individual internodes already present in the buds [1]. It is a natural composite material consisting cellulosic fibres embedded in a lignin matrix. The fibres are aligned along the length of the tree. Over 1200 species have been identified globally [2, 3]. Bamboo has a very long history with human kind. It has been used widely for household products and extended to industrial applications due to advances in processing technology and increased marked demand [4]. In Cameroon, many varieties of bamboo exist in several regions. If raffia bamboo is very resourceful to the people of the West and North-West Regions for the production of the local white wine, traditional housing et various houses equipments (beds, chairs, tables, cupboards), the level of traditional as well as industrial exploitation of Indian bamboo is very pour, despite the existence of many varieties. More recently [5] it has been prove that the bamboo leaves can be used as ash stabilization on lateritic soil in highway construction. Many studies have been done in order to analyze the possibility of using bamboo as substitute to iron in reinforced concrete structures [7,8,9,10,11] or in reinforced matrix polymer [12,13,14]. The “Indian” bamboo grows in humid as well as dry ground. This study aims to characterize the physical properties of three bamboo types: Arundinaria alpina from humid soil (valley), Arundinaria alpina from dry ground (uphill) and Oxytenanthera abyssinica from dry ground (Slender tall). The influence of the position of the sample in a given tree will be analysed.

II. EXPERIMENTAL PROCEDURE

A. **Materials**

The primary material used for this study was *Arundinaria Alpina* and *Oxytenantera abyssinica* (locally called Indian Bamboo), the most widely available species of bamboo of structural value in Cameroon. *Arundinaria Alpina* is the large and very tall bamboo while *Oxytenantera abyssinica* is the slender type. The Bamboo culms for *Arundinaria alpina* were procured from two large clumps. One clump was from humid soil (later called valley bamboo) while the other clumps (uphill bamboo) was from dry soil. *Oxytenanthera abyssinica* was got from dry soil. The culms were cut at 80 cm above ground level. All three species were got from Mbengwi central sub-division in Momo Division of the Northwest Province. Three culms each of *Arundinaria alpina* having lengths ranging from 9.5m to 15m and girth having average diameter of 75mm at the bottom and gradually reducing to 41mm at the top were selected .Three culms of *Oxytenanthera abyssinica* with girth diameter ranging from 40mm at the bottom and gradually reducing to 20mm at the top were also harvested .Both categories of bamboo were procured and the growth bud carefully trimmed for each species of bamboo [3, 4].The average culm wall thickness for *Arundinaria alpina* ranged from 11mm at the bottom to 4mm at the top and the length of internodes was in the range of 115mm to 501mm along the culm length. Bamboo used for the various tests was selected from the innermost part of the clumps .The average culm wall thickness for *Oxytenanthera abyssinica* was in the range of 2mm and the length of the internodes ranged from 75mm to 45mm along the culm length. All the bamboos were harvested in December 2007 because the month is in the dry season which is advantageous for starch reduction [4,5]. Starch is detrimental to the setting of cement [7,8]. The age of bamboo suitable for the experiments is in the range of three to five years and the colour was observed to be turning brown [11,12, 13]. The observation of colour change was not very evident with the valley bamboo but the fact that it was harvested from the interior makes it reliable. These were then seasoned for 12 weeks under ambient temperature conditions while constantly taking the water content. For the purpose of the tests, the bamboo culm length was divided into three equal parts. Therefore each bamboo portion represented one-third of the culm length. At the time of carrying out the tests with seasoned bamboo the moisture content was 86.36% for the valley bamboo, 29% for the uphill bamboo and 30% for the slender bamboo. The girth of the bamboo culm as well as the structure of the bamboo is presented as shown in Figure 1 below. Figure 1a) and b) shows various part of a global bamboo tree. Figure 2 shows the distribution and the orientation of the fibres in a bamboo tree. At the level of internodes, the fibres are strictly parallel (fig. 2 a) while they are distorted at the level of the node where new branches born (fig. 2b). Figure 3 shows how the specimen has been taken from a culm and defines various sections of the specimen.

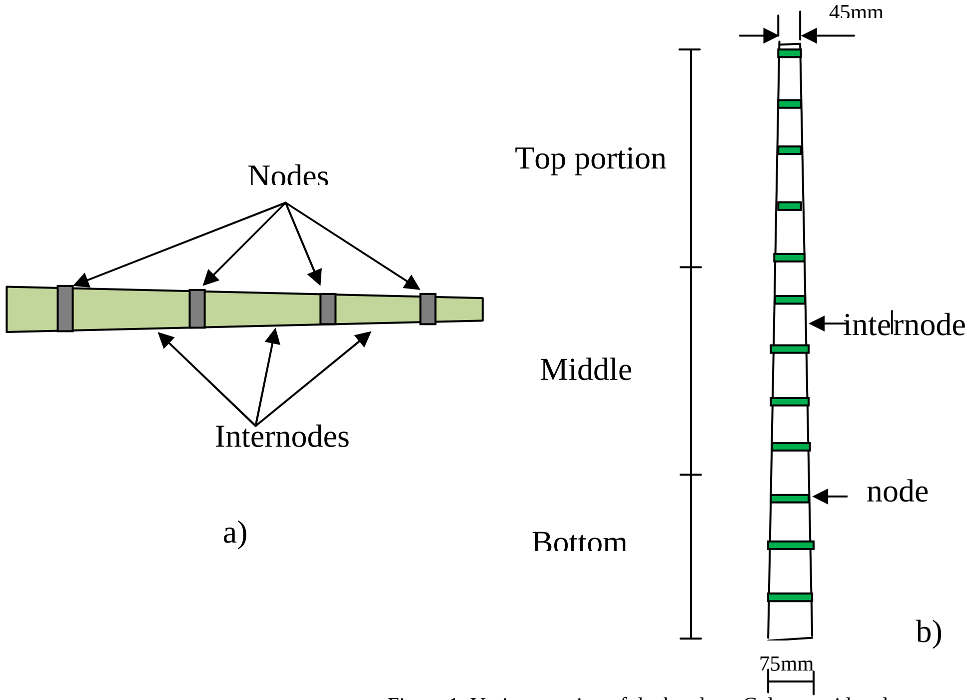


Figure 1: Various section of the bamboo Culm considered

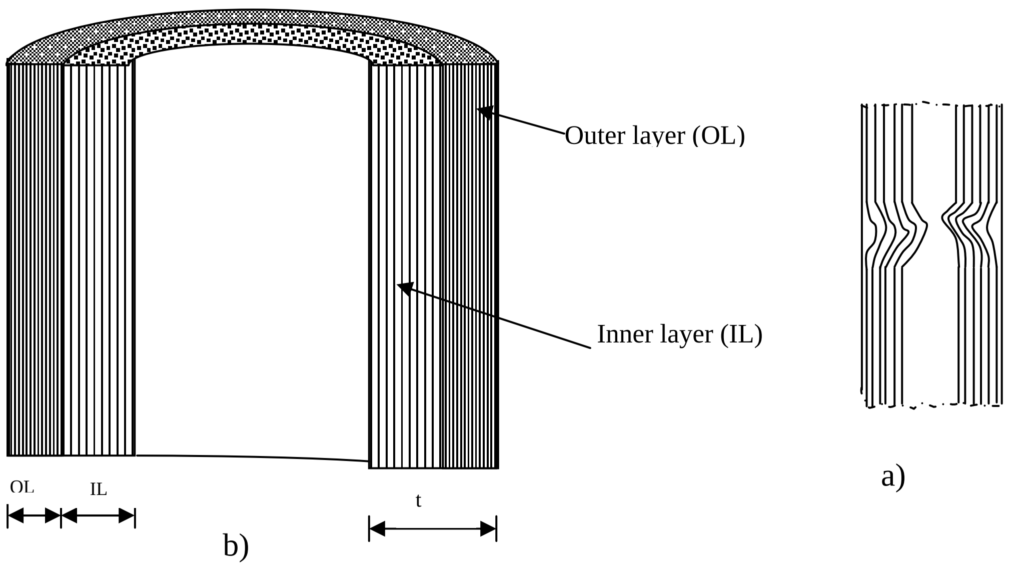


Figure 2: Various layer of the bamboo culm and configuration of fibres for the inner and outer layers

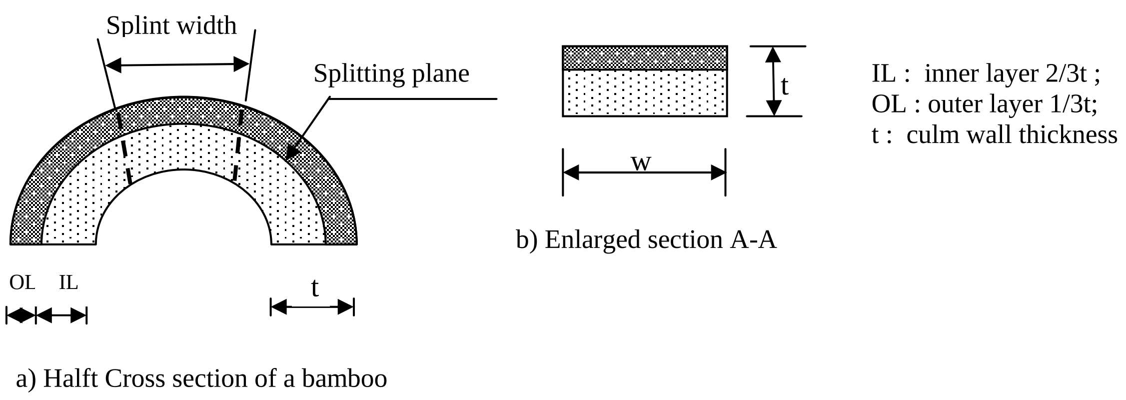


Figure 3 : Definition of the split for the test

B. Methods

1. Densities of Arundiranria and Oxytenanthera Abyssinica

Tests to determine the densities of the bamboo were done using all the species of bamboo under study. This test was done in order to better appreciate the reasons for the variation in the mechanical properties of the different species of bamboo. Three specimens for each specie taken from each portion of the culm were used. The specimens used were splints of 200mm long and 20mm wide. The dimensions were taken with the aid of a measuring rule that had an average precision. Splints of the *Arundinaria alpina* were further split into the outer layer and inner layer respectively. The splitting of the splints was done in order to better understand the difference that may exist between the inner layer and the outer layer. Specimens were weighed with the aid of OHAUS scale balance and the result recorded. The density was then calculated by using the following formula:

$$\rho = \frac{w}{v}$$

where w is the weight of the specimen and v is the measured volume.

2. Porosity of bamboo

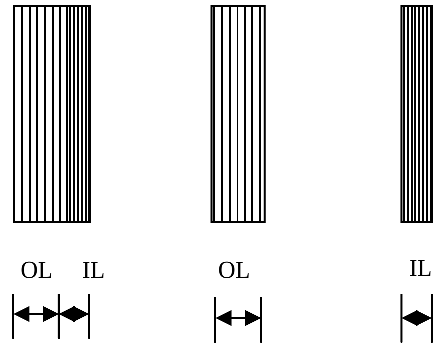
This test was done in order to ascertain the quantity of water that can be absorbed for a given period of time. The absorptivity is the consequence of the existence of open porosity within the material. The test standard used was ASTM D 2395-93. For this purpose, the ambient temperature seasoned culms were split into splints having widths of 12 mm and lengths of 200 mm each from the uphill and valley bamboo. Figure 5 shows the various categories of specimens used for the test. The splints were further split into the outer layer and inner layer to investigate the variance in the absorption rate for the two layers. The outer layer was split at one-third of the wall thickness taken from the outer circumference of the culm while the inner layer was at two-thirds of the wall thickness as shown in (figure 3b) above [9].

The dry weights of each sample was taken using the gold brand model AM 2501 scale balance which had a normal precision .The geometrical characteristics were obtained by carefully measuring with a measuring rule which had an average precision. The test was done in five time phases of varying interval. The first three phases were done with time intervals of 10 minutes each and the fourth and fifth intervals had time intervals of 24hours each. Specimens were immersed in water at room temperature after the initial weights w_0 had been measured and recorded. At the end of each interval the final weights, w(t) were recorded and then the percentage of absorption was calculated using the following formula:

$$p(t) = \frac{w(t) - w_0}{w_0}$$

where: w_0 is the initial weight,w(t) is final weight. The quantity w(t)-w_0 represents the quantity of water absorbed and the percentage of absorption represents the volume of the pores in the material. The test have been conducted for 0.5hour, 24 hours and 72 hours, this last time corresponding to the full water, and the corresponding parameters the real porosity of the material.

(a): Various types of specimens



(b): Split splints

Figure 5 : Various specimen of the bamboo culm

3. Shrinkage

Three specimens for the shrinkage test were splints procured from the green culms of the uphill and valley bamboos respectively. The dimensions were 12mm wide, 200mm long and the thickness was in varying proportions depending on the position of the specimen on the culm. Figure 5 a and b below shows the geometrical characteristics of the specimens used. The radial, tangential and longitudinal shrinkage rates were investigated. The shrinkage in this case could be as a result of the water the bamboo holds in its green state or water absorbed by bamboo and the subsequent progressive seasoning. The result would be useful in determining the kind of treatment to be done on the bamboo before its utilization as a structural material. Bamboo shrinks when seasoned [9].The width, length and thickness of each specimen were carefully measured with the aid of a measuring rule of average precision. These specimens were then dried in the oven after weighing them. The temperature of seasoning was 550°C. The period of seasoning was 90 minutes. After the seasoning period was over, the final dimensions were carefully measured and recorded. The percentage volume changes were calculated and recorded. The following formula was used to calculate various dimensions change :

- For radial variation,

$$\varepsilon_r(t) = 100\frac{d(t) - d_0}{d_0}$$

Where, d_0 is the initial radial dimension, d(t) is the final radial dimension

- For tangential variation,

$$\varepsilon_t(t) = 100\frac{t(t) - t_0}{t_0}$$

Where, t_0 is the initial tangential thickness, t(t) is the final tangential thickness at the moment of measurement

- For longitudinal variation,

$$\varepsilon_l(t) = 100\frac{l(t) - l_0}{l_0}$$

Where, l_0 is the initial longitudinal dimension, l(t) is the final longitudinal dimension.

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Figure 6: Photo of the oven used for the drying of the specimen

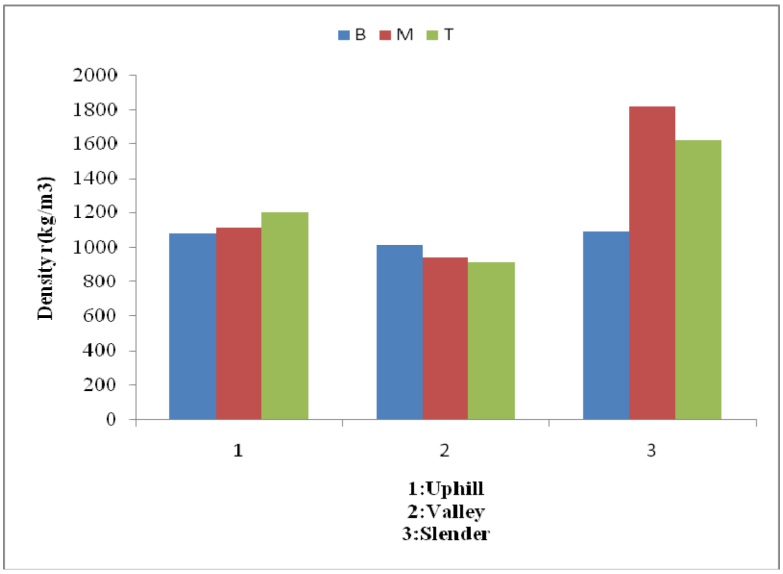
III. RESULTS AND DISCUSSION

1. Effect of the position on a tree and the origin of the culm

Figure 7 shows that the density of uphill and slender bamboo increases from bottom to the top section of the tree while the valley bamboo has an inverse behaviour. These results showed that the uphill bamboo *arundinarialpine* generally has a higher density, when compared to the valley bamboo and slender bamboo respectively. The oxytenanthera abyssinica bamboo showed the highest density when compared to *arundinaria lpine.* This could be an indication to the fact that the slender bamboo has a greater fibre concentration than *arundinarialpine*. The general trend showed that the densities as well as porosity increase from bottom to top as concerns internodes but the reverse trend was true for the specimens with nodes. This variation could be a result of the fact that the fibres along the culm do not have the same structure and concentration. The effect of the diameter wall thickness are also responsible for variance in physical and mechanical characteristics along the Culm even within internodes the fibre lengths are not the same [17,18]. Further research is required in order to have a clear idea of the difference in fibre configuration along the culm of both the valley and uphill bamboos. Bamboo varies within and among species [19,20]. In other hands, the specimen with nodes seems to have better density when comparing with the one without node, because of the special arrangement of the fibres and the matrix at this zone. At the same time it can be seen that the porosity in this zone seems to be greater.

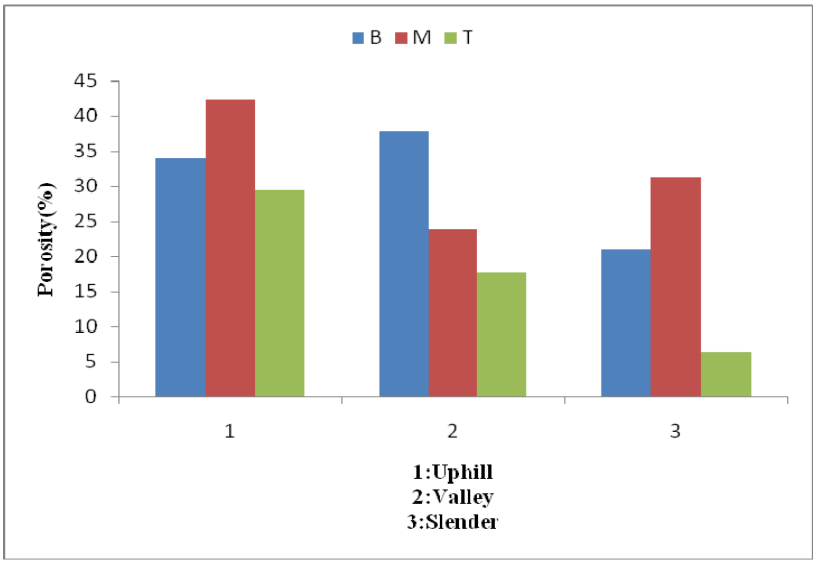
On figure 8, the porosity of the specimen without node, seems to decrease approximately from bottom to top, while the uphill bamboo has a greater porosity, when compared to the valley and slender. The specimens with node have greater density than the one without node. Figure 9 and 10 show respectively the effect the node on the density and the porosity of various bamboo. The density vary respectively between 1160 and 1530 kg/m3, 1140 et 1430 kg/m3 et 1510 et 1960kg for uphill, valley and slender. The scattering of the results observed for the various measures is the consequence of the random distribution of the fibres in lignin matrix. This scattering increases at the level of the node because of disruption of the distribution of the fibres.

Table 1 presents comparative results between the specimen with node with the one without node. Despite the scattering aspects of the results due to the random distribution of the fibres, it appears that the node has a visible effect on the density which is in average greater in the presence of the node than for the one without node.



B : Botton; M : Midle; T :Top

Figure 7 : Effects of tree origin and the position on a tree on the density of bamboo without node



B :Botton, ;M :Midle ;T :Top

Figure 8 : Effects of tree origin and the position on a tree on the porosity of bamboo without node

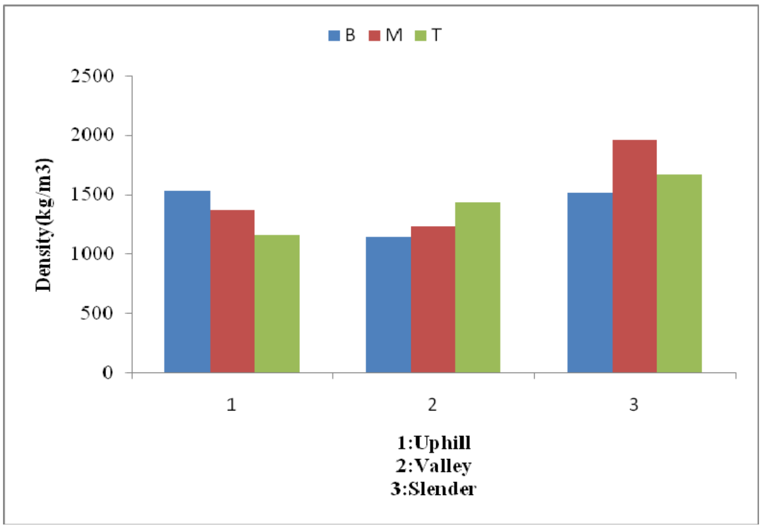


Figure 9 : Effects of tree origin and the position on a tree on the density of bamboo with node

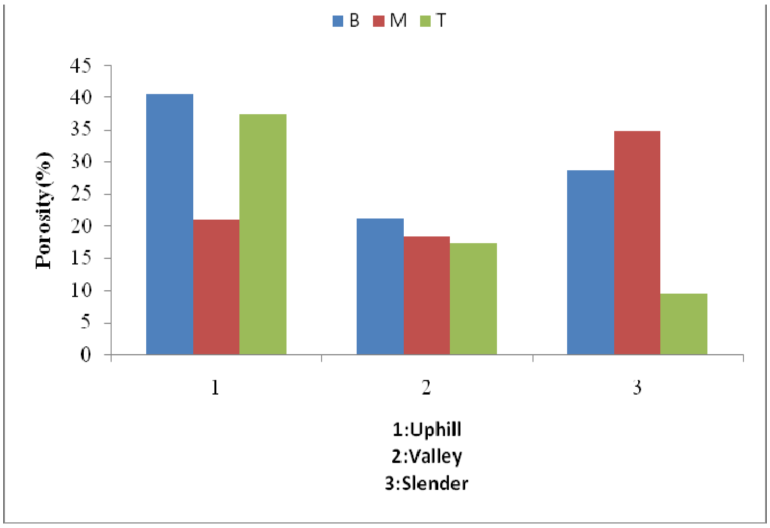


Figure 10 : Effects of tree origin and the position on a tree on the porosity of bamboo with node

Table 1: effects of nodes, of the position and the growing zone

Zone	**Position**	**Density**		**Porosity**	
		Without node	**With node**	**Without node**	**With node**
Uphill	Bottom	1080	1530	34	40,63
	Middle	1110	1370	42,3	21
	Top	1200	1160	29,4	37,5
Valley	Bottom	1012	1140	37,8	21,26
	Middle	937	1230	23,75	18,34
	Top	909	1430	17,6	17,2
Slender	Bottom	1090	1510	20,96	28,57
	Middle	1820	1960	31,1	34,87
	Top	1650	1670	6,38	9,38

2. Effect of splits on the physical properties

The outer layer occupies about 30 percent of the wall thickness [9]. It also investigated that the outer layer alone represents 59.69 percent of the combined stress while the inner layer represents 40.31 percent. If the inner layer of the wall that represents 70 percent is completely removed and replaced by the outer layer alone to occupy the entire cross-sectional area, the performance of the system will increase by 238.1% . For the inner part, the uphill performed better than the valley. This situation can be attributed to a higher degree of fibre density dispersion found in the inner part of the valley bamboo. Generally the stresses on both the valley bamboo and the uphill bamboo increased from bottom to top. The internodes of the uphill bamboo shows a more ductile behaviour than the across node while the there was a near brittle behaviour for the internodes and the across node for the valley bamboo. For the split splint the outer layer was more ductile the than inner layer for the uphill bamboo where as for the valley it showed that the trend for the inner and the outer layers were almost the same but for the only ductile behaviour at top portion for the outer layer The slender bamboo showed that the acrossnode were completely brittle while the internodes were ductile. Generally the uphill internodes showed a more ductile behaviour than the valley bamboo and the same trend was observed with the split splints.

Table 2: Density and porosity of split splints of bamboo

Bamboo Specie	**bamboo portion**	**culmlayer**	**ρ (kg/m^3)**	**Porosity %**
UPHILL *arundinaria alpina*	**B**	**IL**	323.4	27.6
		OL	1579	15.6
	M	**IL**	1093	24.2
		OL	1678	16.11
	T	**IL**	1125	23.23
		OL	1690	7.41
VALLEY oxytenanthera abyssinica	**B**	**IL**	815.7	53.03
		OL	1839	41.45
	M	**IL**	777.7	52.44
		OL	1858	32.74
	T	**IL**	998.8	50.18
		OL	2371.4	23.28

a. Effect of the position on a tree and the origin of the shrinkage of bamboo

Figure 11 and 12 show the effect of the position and the origin of the tree on the various shrinkage of the bamboo. It appears from those results that, the shrinkage can be neglected in the longitudinal direction, while it is very important for the radial direction. The shrinkage characterizes dimension change due to the movement of the water in the specimen. Since the bamboo is a composite constituted of one direction fibres embedded in a lignin matrix. The water is the principal constituent of the lignin matrix, and since the volume of water is very low in the fibres,

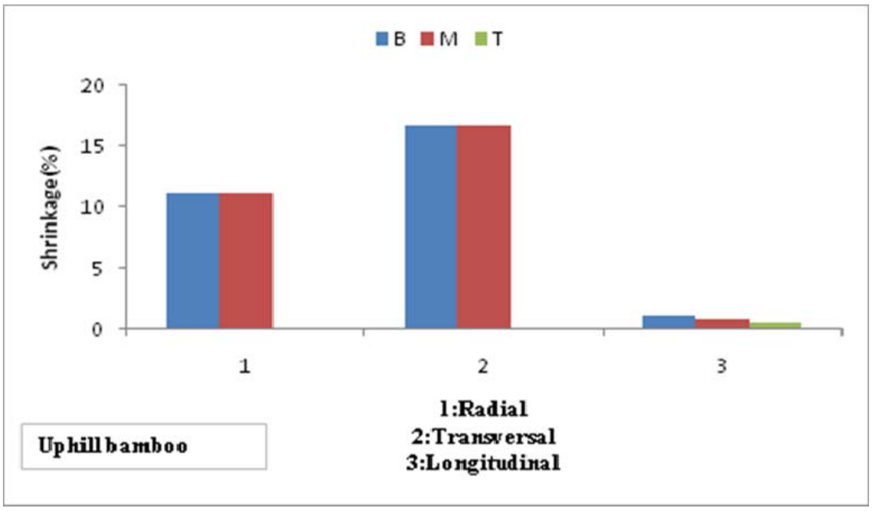


Figure 11 : Variation of the shrinkage for various direction in the tree for uphill bamboo

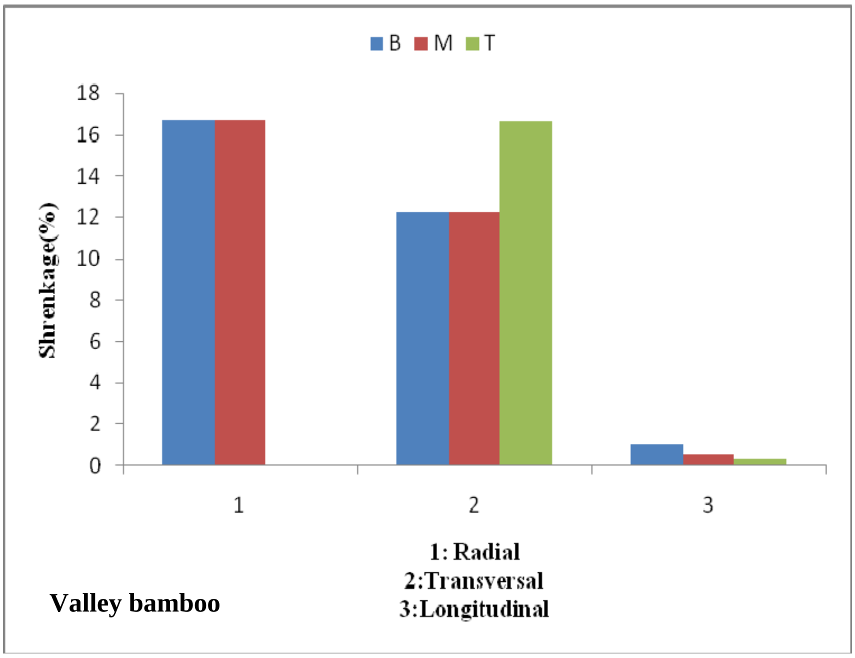


Figure 12 : Variation of the shrinkage for various direction in the tree for valley bamboo

IV CONCLUSION

Bamboo (*ARUNDINERIA ALPINA*) presents very high values in its physical properties. The uphill bamboo proved denser than the Valley bamboo while the slender specie *oxytenanthera abyssinica* showed the highest value when compared to both the uphill and the valley *arundinaria alpina*. The physical properties increase from the bottom to the top, despite the scattering due to random distribution of the fibres within the lignin matrix. The shrinkage seems to be more important for the radial direction than in transversal direction. About the variation in the thickness direction, the outer layer are more dense because the density of fibres per meter square is more important.

REFERENCES

[1] Volker kleinhenz and David J. Midmore,*'Aspects of bamboo agronomy'*, Advances in agronomy, Vol 74, 2001.

[2] Derek R. Ritch,*'Splitting Capacity Characterization of Bamboo culm'*, bachelor of philosophy thesis, university of Pittsburg Honor College, 2009, 89 pages.

[3] Ayedemi A. Y. and Fagbenle O. I, '*The influence of anatomy and mode of seasoning on the properties of bamboo'*, Master thesis, Obaf emi Awolowo University, Ile Ife, Nigeria, 1999, 76pages.

[4] Jinxing L. Xinqiang H., Tigyun K. And Ceulemans R., '*Lignification and lignin heterogeneity for various classes of bamboo(phyllostachys pubeaens)'*, Physiologia planetarium, 114, pp. 296-302, 2002.

[5] Wang D., S. J. Shen,*'Bamboo in China'*, Timber Press, Portland, Oregon, pp. 428, 1987.

[6] Lakka S. C., and J. M. Patel,*'Mechanical properties of bamboo, a natural Composite'*, Fiber Sciences Technologies, 14, pp. 319-322, 1980.

[7] Olughenga O. Amu, and Akinwole A. Adeuberu,*'Characteristics of bamboo Leaf Ash stabilization on Laterite Soil in Highway Construction'*, International Journal of Sciences and Technology, Vol. 2(4), pp. 212-219, 2010.

[8] Harish Sakaray, N. V. Vamsi Krishna, I.V. Ramara Reddy, '*Investigation on properties of bamboo as reinforcing materials in Concrete'*, International Journal of Engineering research, Vol. 2(1), pp. 077-083, 2012.

[9] Leena Khare,' *Performance Evaluation of Bamboo reinforced Concrete Beams'*, Master of Civil Engineering Theisis, University of Texas at Arlington, December 2005, 87 pages.

[10] Hidalgo O.' *Study of mechanical properties of bamboo and its use as Concrete reinforcement : Problems and solutions'*, Centro Interamericana del Bambu(CINBA), Bogota, Colombia, 1992.

[11] H. M. A. Mahzuz, Mushtaq Amhed, Md. Asrafuzzaman, Rejaul Karimaud Raju Ahmed,*'Performace Evaluation of bamboo with Mortar and Concrete'*, Journal of Engineering and technology researche, vol.3(12), pp. 342-350, November 2011.

[12] L. Gyansah and S Kwofie,*'Effects of notched design on the performance of Bamboo'*, Research Journal of Environmental and Earth Sciences, Vol. 4(1), pp. 8-15, 2012.

[13] Omobowale M. O. And Ogedengbe K.,*'Trends in fibers Characteristics of Nigerian grown Bamboo and its effect on its impact loa d and tensile strength'*, Bamboo Science and Culture 21(1), pp. 9-13,2008.

[14] Xiabo Li,*'Physical, chemical and mechanical Properties of bamboo and its Utilization Potential for Fiberboard Manufacturing*', Master of sciences Thesis, Faculty of Lousiana State University and agricultural and Mechanical College, May, 2004, 76 pages.

[15] Derek R. Ritch,*'Splitting Capacity Characterization of Bamboo culm'*, bachelor of philosophy thesis, university of Pittsburg Honor College, 2009, 89 pages.

[16] Leena Khare,' *Performance Evaluation of Bamboo reinforced Concrete Beams'*, Master of Civil Engineering Theisis, University of Texas at Arlington, December 2005, 87 pages.

[17] Zp Shao,, L. Zhou1, Y. M Liu1, ZM Wu1 & C Arnaud *'Differences in structure and strength between internode and node section of Moso Bamboo'*, Journal of Tropical Forest Science 22(2), pp. 133–138, 2010

[18] Yu H. ' *Study on property of bamboo culm'*, World Bamboo and Rattan 1: 5−10, 2003.

[19] Yu Hq, Jiang Zh, Hse Cy& Shupe Tf., '*Selected physical and mechanical properties of Moso bamboo (Phyllostachys pubescens)'*, Vol. 20, pp. 258–263. 2008

[20] Moe Moe Twe, Kin Lio,*'Effect of Environmental aging on the mechanical propertie of bamboo-glass fiber reinforced polymer matrix hybrid composites*',Composites: part A: applied Sciences and Engineering, 33, pp. 43-52, 2002.

[21] H. M. A. Mahzuz, Mushtaq Amhed, Md. Asrafuzzaman, Rejaul Karimaud Raju Ahmed,'Performace *Evaluation of bamboo with Mortar and Concrete'*, Journal of Engineering and technology researche, vol.3(12), pp. 342-350, November 2011.