IJESRT: 8(3), March, 2019 ISSN: 2277-9655

International Journal of Engineering Sciences &Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

Website: www.ijesrt.com Mail: editor@ijesrt.com

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EFFECT OF ANALYSIS ON MORPHOLOGY OF BAMBOO FIBER: A REVIEW

Yalew Dessalegn*[1]& Dr. Balkeshwar Singh[2]
*[1]Research Scholar, Department of Mechanical Design & Manufacturing Engineering,
Adama Science & Technology University, Adama City, Ethiopia
[2]Professor, Department of Mechanical Design & Manufacturing Engineering,
Adama Science & Technology University, Adama City, Ethiopia

DOI: 10.5281/zenodo.2583738

ABSTRACT

This review paper analysis the effect on the properties of bamboo fibres based on its morphology. The properties of the bamboo fibres are analyzed using different microscopes that are Macroscope, Mesoscope, Microscope, Electron scan microscope and Infrared spectroscopy, optical microscopy is showing the macroscopic features of fibres examined (longitudinal and cross-section views). IR absorption spectroscopy is the basis for fibre material identification, scanning electron microscopy (SEM) is to show the differences in the morphological structure of the fibres investigated (a fibrillar structure). Bamboos are members of the grass family, distinguished from other grasses by their woody stems, branched growth and often by their large size. Morphology is the study of the size, shape, and structure of bamboo and their relationship of constituent parts that are determined their identity so that we are reviewing and analyzing the effect of morphology on the bamboo fibre. The properties of the bamboo fibres are affected by the helix angle of the fibre, the diameter of the fibre, aspect ratio not only those but also the constituent percentage of cellulose, hemicelluloses and lignin has impact on it. The cause of morphological variation of bamboo is the effect of location and position of the culm, environmental effect, species type, and age.

KEYWORDS: Bamboo, Morphology, microscope.

ABBREVIATION

SEM	Scan Electron Microscope;	MFA	Micro fibril Angle;
IR	Infrared;	FITR	Fourier Infrared Transform Ray;
NF	Natural Fibres;	TGA	Thermogravetic Analysis;
LM	Lumen in Middle;	MOR	Modulus of Rapture;

1. INTRODUCTION

Bamboos are graceful, airy plants that are easy to grow, but some may take a lot of management to control unwanted spread. There are forty-five genera of bamboo, which includes about 1200 species, many tropical, with a wide range of forms. They range in size from dwarfs that are only 12 inches tall to giant types that tower up to 60 feet tall. A few bamboos have variegated foliage and some have very attractive canes of rose, burgundy, yellow, orange, gray or black. Although many types of bamboo are tropical there are also many that grow in temperate regions as well [1].The heavier a car is, the greater its fuel consumption and CO_2 emissions. Mass reduction is therefore an effective measure to reduce a car's emissions. However the current EU CO_2 target system offers little incentive to reduce the mass of vehicles: the lighter a manufacturer's fleet, the lower its assigned CO_2 target. If the manufacturer reduces the mass of its vehicles, it must then also achieve a lower g/km target. This evaporates most of the manufacturer's weight-reduction advantage, and it will usually pursue other alternatives to reduce CO_2 emissions [2].

Moisture within a NF can greatly affect mechanical performance of a composite; NFs should be dried before composite manufacture with thermosetting resins to ensure optimum performance. Residual moisture should also be taken into account when comparing fibre treatment methods since the difference in performance between the methods could be down to differences in the residual moisture[3].As in other bamboos, the culm tissue of G.angustifoliais made up of: cortex (epidermis, hypodermis & cortical parenchyma), parenchyma cells, fiber,

and vascular bundles, which in turn are made up of sclerenchyma cells, vessels (metaxylem, phloem and protoxylem) and sieve tubes with companion cells [4].

2. ANALYSIS BAMBOO MORPHOLOGY ALONG AND ACROSS THE CULM

Fiber length

The results for the fiber length study showed in Table-1 indicate significant differences between the positions and portions. The fiber length obtained for internodes were 2074.24 µm and nodes 1672.62 µm. The fiber lengths were longer at the internodes compare to the nodes. At the internodes, the anatomy structure was consistent but at the nodes it was quite twisted. The anatomical factor, may be contribute the different fiber length between two positions. The fiber lengths for outer layer position were 1698.52 µm, middle layer 2060.41 µm and for inner layer was 1861.35 µm. Significant differences were observed in the fiber length at the internodes, nodes and between the cross-sectional position of the bamboo [5].

Fiber diameter

The fiber diameter at different position showed that the nodes have larger fiber diameter at 22.04 µm and internodes at 18.23 µm (see Table-1). Significant different existed between the fiber diameter in position at the internodes and nodes. The fiber diameter at different position showed that the outer layer were 18.49 µm, middle layer 22.36 µm and inner layer 19.56µm.

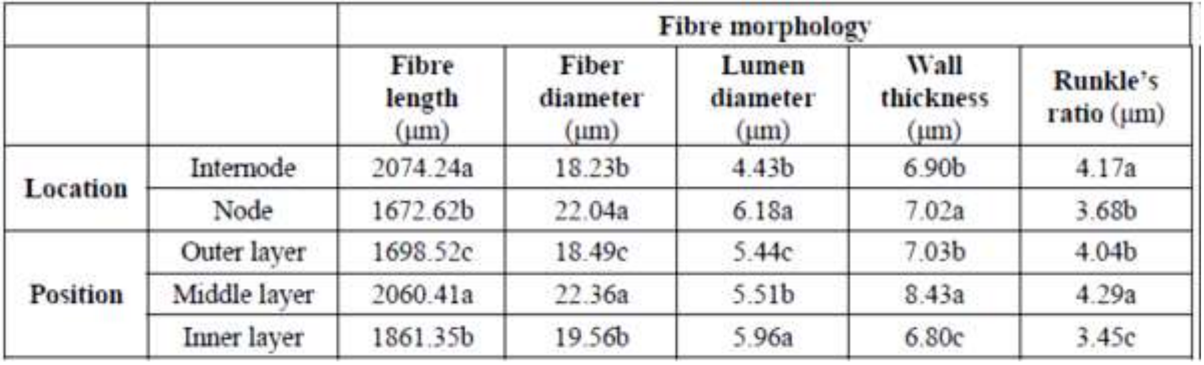
Lumen diameter

The lumen diameter was 4.43 µm at internodes and 6.18 µm at the nodes (shown in Table-1). The diameter at different position showed that the outer layer was 5.44 µm; middle layer 5.51 µm and inner layer 5.96µm.

Wall thickness

The fibres wall thickness was 6.90 µm at internodes and 7.02 µm at the nodes (Table-1). The thickness at different position showed that the outer layer were 7.03 µm, middle layer 8.43 µm and inner layer 6.80µm. The results showed the wall thickness are thicker at the nodes as compare to the internodes and it was a significantly difference between this two position. The mean average for wall thickness at difference position showed that at the outer layer was 7.03 µm, middle layer 8.43 µm and at the inner layer was 6.80 µm [5].

Table-1. Analysis of variance for fibre morphology between location and position [5].



		Fibre morphology				
		Fibre length (µm)	Fiber diameter (µm)	Lumen diameter (µm)	Wall thickness (µm)	Runkle's ratio (µm)
Location	Internode	2074.24a	18.23b	4.43b	6.90b	4.17a
	Node	1672.62b	22.04a	6.18a	7.02a	3.68b
Position	Outer layer	1698.52c	18.49c	5.44c	7.03b	4.04b
	Middle layer	2060.41a	22.36a	5.51b	8.43a	4.29a
	Inner layer	1861.35b	19.56b	5.96a	6.80c	3.45c

Values followed by the same letter in a column is not significant different at 95% probability level

As shown in the figure-1 the cross sectional structure of Guaduaangustifoliaculm is surroundedby four schlerenchyma sheaths, two located at each side of the metaxylem vessels, another one around the protoxylem (intracellular space) and a final one around the phloem. The sclerenchyma sheaths of the phloem are more prominent in the middle and inner zone bundles, which are the ones used for anatomical classification. In the vascular bundles of the periphery and transition zones, the sclerenchyma sheath is more prominent towards the protoxylem (Figure-1). One to two layers of thick walled parenchyma were also observed surrounding the metaxylem.

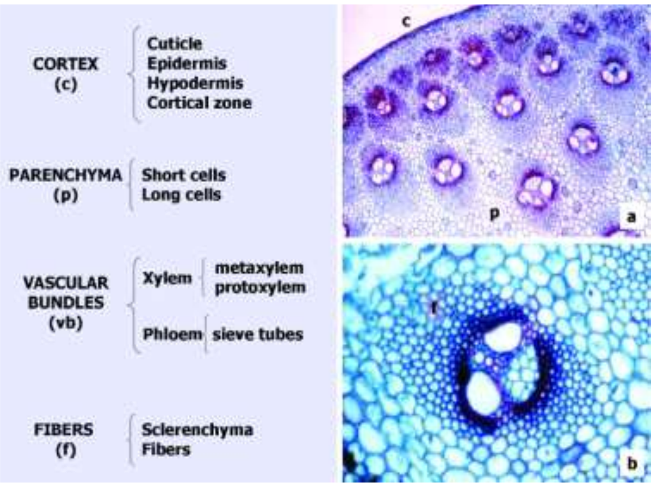


Figure-1. cross sectional structure of Guaduaangustifoliaculm: a. transversal section; and b . detail of vascular bundle [4].

2.1. Diameter, wall thickness and internode length of the bamboo culm

As shown in Figure-2 (a) and (b), the bottom segment has the largest diameter and wall thickness, but the average internodes length is lower in comparison with the other segments. These characteristics make the base of the culm suitable to carry compressive loads. The diameter and thickness of the wall decrease from the bottom to the top. It was found for Moso bamboo (Phyllostachyspubescens) that the length of the internodes reaches the maximum length value of 32 cm in the middle section of the bamboo plant [6].

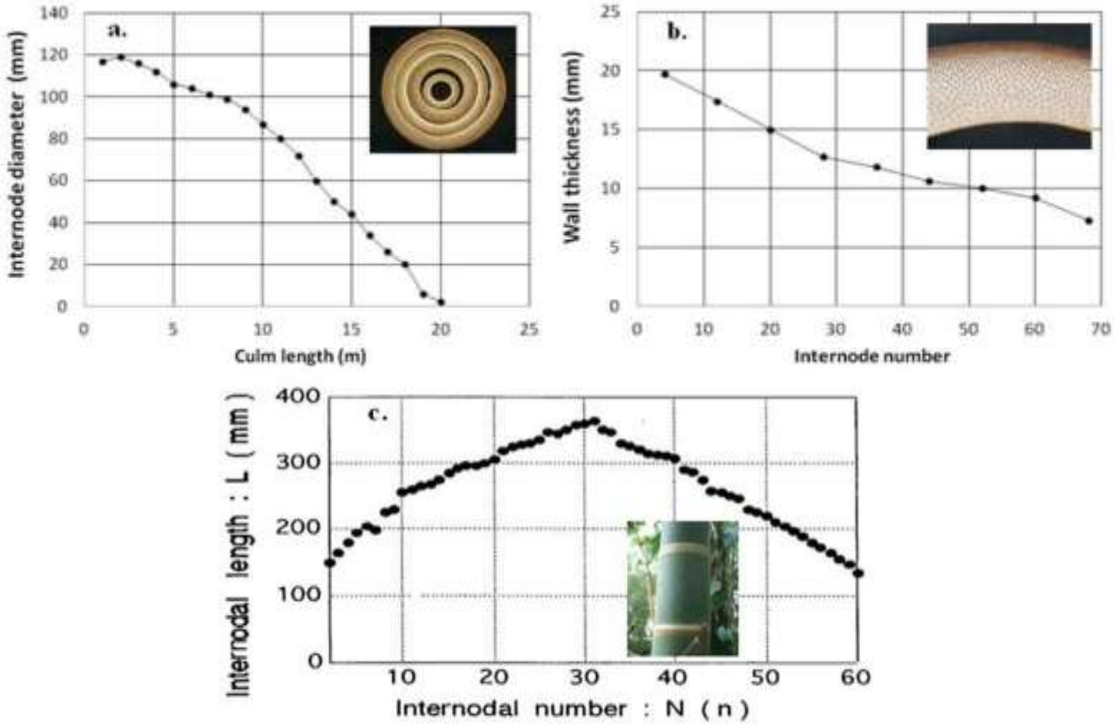


Figure-2 (a) Internodal diameter & Culm length, (b) Wall thickness & internode number and (c) intermodal length & intermodal number [6].

2.2. Bamboo fibre Morphology

Bamboo culms are hollow, and every Culm from inner side is divided by several diaphragms which are seen as rings on the outside. The part between two rings is called "Internodes" where branches grow. Distance between each node varies and it depends on the type of the species. The microstructure of a bamboo Culm consists of many vascular bundles which are embedded in parenchyma tissue and distributed through the wall thickness. Parenchyma tissue only keeps the vascular bundles in the longitudinal direction. The number of vascular bundles is highly concentrated close to the outside of the bamboo Culm wall, and this amount reduced on the inside. They involve vessels, sclerenchyma cells, fiber strand and sieve tubes with companion cells. The fiber strand consists of many elementary fibers with the shape of hexagonal and pentagonal, where Nano-fibrils are aligned and bounded together with lignin and hemi-cellulose. The strength of a bamboo Culm is defined by its vascular bundles.

2.3. Morphological hierarchy of bamboo

As shown in the figure-3 (a) the bamboo culms consisted of wall, diaphragm, Node and inter node in one full length of the bamboo plant so that the internodes and the wall thickness depended on the age and the species of the bamboo which effected on the properties of the bamboo fibres. At the node parts of the bamboo discontinuous of the fibres have formed so that it could not be used for fibre reinforced composites due to poor mechanical properties where as the parts of internodes of the bamboo continuous of the fibres have formed so that it could be used for fibre reinforced composites moreover it has good mechanical properties **[7]**

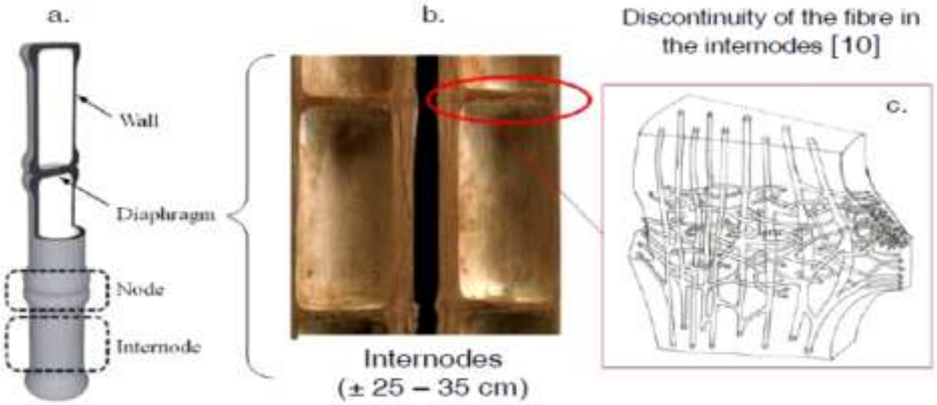


Figure-3. Fibre bundle discontinuity into the bamboo culm. (a) bamboo culm, (b) internodes and (c) schematics for the discontinuity in the node.[7]

Figure-4. Morphological hierarchy in bamboo[8]

The length and diameter of the technical fibres guarantee a suitable aspect ratio which is an important factor for a reinforcing material. Also, the high elementary fibre content within the technical fibre bundle assures that more than 80% of the modulus of the elementary fibres is transferred to the technical fibre after the extraction process [8]

As shown in the figure- 4 according to the largest to smallest size of the morphology hierarchy in bamboo fibres are Bamboo culm, technical fibre (Bundle fibre) and elementary fibres respectively. The diameter and the length of bamboo culms are 6-11 cm and 23 cm respectively. The application area of bamboo culms are for structural such as house hold furniture, the construction of the house and decoration application. The mechanical properties tensile strength and young`s modulus of the bamboo culms are 237MPa and 16 GPa respectively. The scan electron microscope of technical fibres( Bundlefibres) are the vascular bundle of elementary fibre. The size of the technical fibres are the diameter 200-400µm and length 20-34 cm and the tensile strength and young`s moudlus of the technical fibres are 800MPa and 43GPa respectively. The smallest and the shortest size of the bamboo fibres are the elementary fibres The diameter and the length of elementary fibres are 12-20 µm and 1.3 mm respectively and the tensile strength and young`s modulus of the elementary fibres are 1150 MPa and 50GPa respectively. The mechanical properties of the elementary fibres are comparable with glass fibres. Regarding to the better mechanical properties of elementary fibres are used for construction of air plane and automobile parts.

Greater internodal lengths correspond to lower load influences on the final mechanical properties of the composite, because fewer numbers of internode sections will be included in the final composite panels. Likewise, larger culm diameters correspond to higher numbers of extracted strips. Moreover, during the extraction process, only the outer section of 3 mm in thickness is considered, as it provides the best structural properties. Preliminary results performed in show that the inner region has up to 40% lower mechanical properties compared with the average value from the outer region due to increase in the volume fraction of bamboo fibers. These values are in line with those in other studies on the bamboo culm. Furthermore, the section of the bamboo culm considered to perform the extraction process was the middle region called “Baza”, due to it good balance between in mechanical properties and morphology conditions (thickness wall, culm diameter and length)[9].

2.4. Microstructure of Bamboo vascular bundles

Vascular bundle is a group of elementary fibres which represent the main structural component of the bamboo culm and they exhibit a hexagonal or pentagonal shape; the small hole in the centre of each elementary fibre is called lumen (Figure-5(f)). As shown in Figure-5 (e) and (f), the proportion of lumen tends to be higher towards the periphery of the fibre bundle close to the parenchyma tissue which means that during the extraction process and the further refining of the fibre, it is desirable to remove part of these peripheral elementary fibres to reduce on one hand the technical fibre diameter and on the other hand the presence of big lumens which may lead to a high void content in the final composite. In the elementary fibres, the wall represents on average 96% of the total area. The middle lamella has a thickness of around 0.5 mm [8].

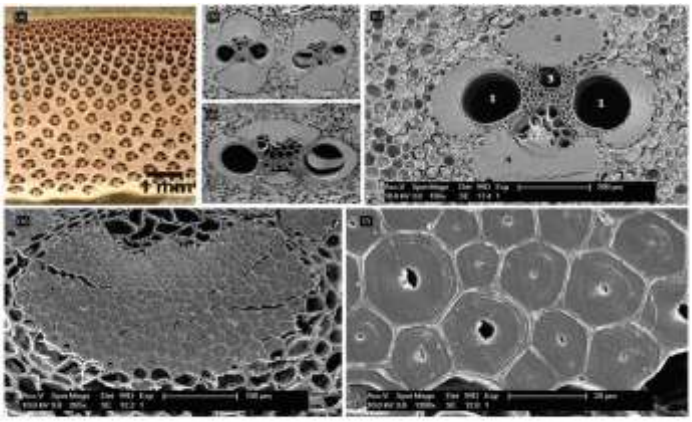


Figure-5. (a) Distribution of vascular bundles in the bamboo wall (G. angustifolia). Morphology of the vascular bundles of G. angustifolia. (b) Outer, (c) middle and (d) inner section of the bamboo wall. Vascular bundle parts: vessels (1), phloem (2), protoxylem (3), fibre bundles (4) and parenchyma tissue (5). (e) Bamboo fibre bundle; the bean-shaped bundle breaks up into a few technical fibres upon extraction. (f) Elementary bamboo fibres [8].

2.5. Elementary Bamboo fibre microstructure

An ultra-hierarchical structure of BF over different length scales has been proposed and is shownin Figure-6.Tiny spindle-like short fibers, tapered at both ends, are intercalated longitudinally with each other along the culm. Lamellation of BF consists of alternating broad and narrow layers with differing fibrillar orientation, which is different from polylamellate structure in lumber . An important feature in the ultrastructure of the wall is the variability in the orientation of the cellulose fibrils with respect to the longitudinal cell axis within different cell wall layers. The narrow layers possess a large microfibril angle indicating the cellulose fibrils are oriented almost perpendicular to the main cell axis, whereas the broad layers show a rather low microfibril angle which means that the cellulose fibrils are oriented basically parallel to the cell axis. The degree of lignification varies remarkably across the fiber wall, with higher lignin content in the narrow layers. Lignin fills the spaces in the cell wall between the cellulose, hemicellulose and pectin components, and holds the cellulose microfibrils together. Besides the common matrix components of secondary walls (mainly celluloses and lignin), crosslinking glycans play a major role in maintaining the structural integrity of the wall through their tight association with cellulose microfibrils.

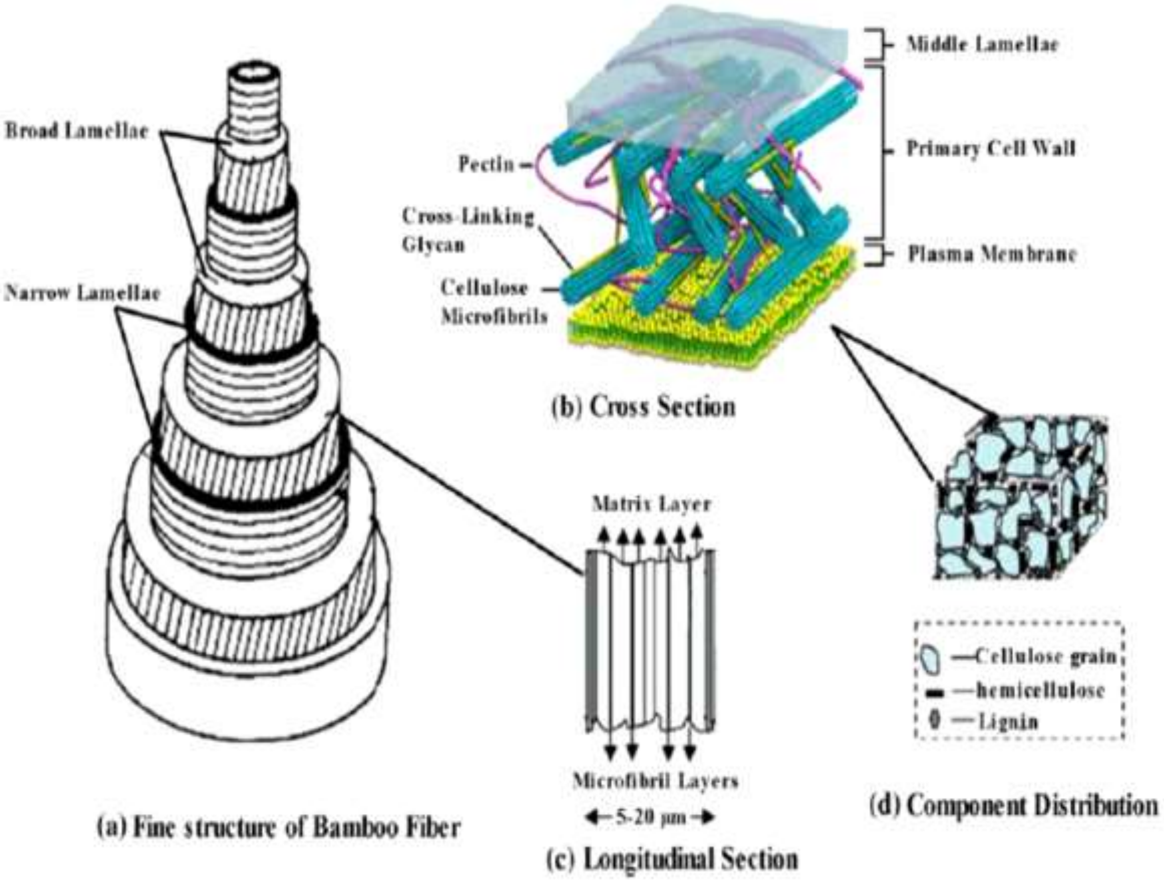


Figure-6. (a) Model of the polylamellate wall structure of a bamboo fiber. The fiber cell wall exhibits a polylamellate structure with alternating broad and narrow lamellae. The narrow layers consist of unidirectional microfibril layers, alternatively in transverse and longitudinal lamellae, with orientation 2–200/ 85–900; the broad layers are the matrix. (b)The middle lamella is the outer-most layer, followed by the primary wall. (c) The spindle-like short tiny fibers, tapered at both ends, are intercalated longitudinally each other along the culm. (d) Nanoscale cellulose grains with orientation and other distributed components[10].

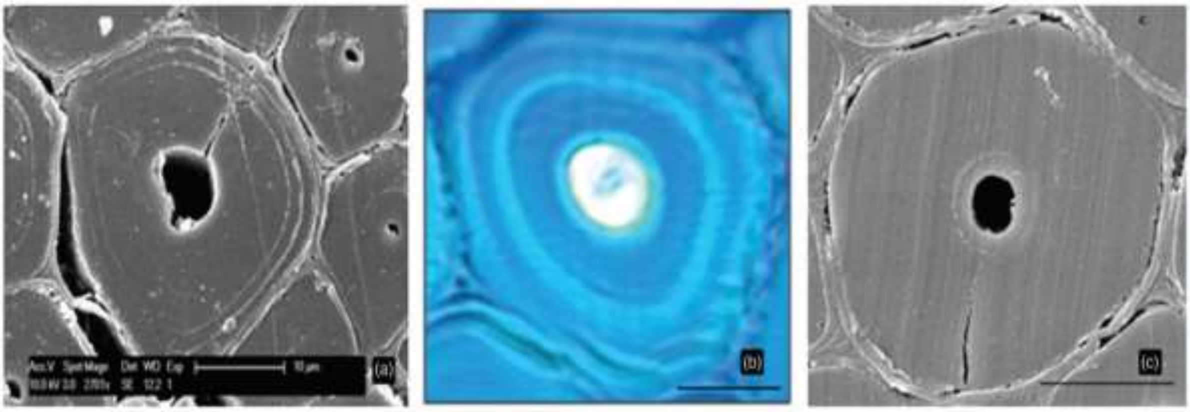


Figure-7. Polylamellate structure of elementary bamboo fibres: (a) Layering visible at the periphery of the fibre bundle, (b) layering visible under light microscope (LM) and (c) typical elementary fibre where layering is not visible. Scale bar 10 mm.

In general, elementary fibres in the outer zone have 2–4 layers and in some cases five layers were visible under LM (Figure-7(a) and (b)). Figure-7(c) shows an elementary fibre where there is not an obvious layering of the wall and this characteristic was predominant for the bulk of the observed elementary fibres.

MFA Figure-8(a) shows a detail of the secondary wall of an elementary fibre, after the chemical treatment where the primary wall has been etched away. The properties will be somewhat reduced due to the visible 'wavy' pathways of the microfibrils. Figure-8(b) shows a detail of the primary wall; the image is of a pulled-out elementary fibre at a fracture surface from a single fibre tensile test. The 90^0 orientation of the microfibrils will provide some off-axis mechanical performance.

Some elementary fibres at the periphery of the fibre bundle show a more multilayered structure being more prone to have different MFA. Figure-8(c) shows an elementary fibre with fibrils oriented at an angle of ~ ±30°; this sample was obtained from elementary fibres present in the outer layer of the fibre bundle close to the parenchyma tissue [8].

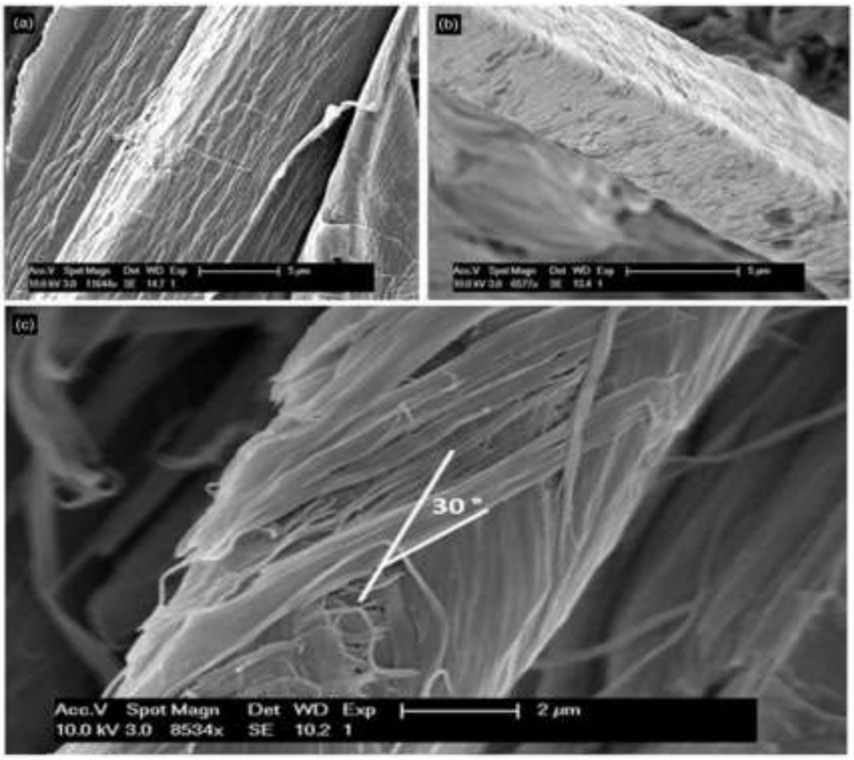


Figure-8. SEM images of elementary fibre microstructure: (a) secondary wall, (b) primary wall and (c) microfibrils oriented at an angle of ~ ±30° [8].

2.6. Scan Electron Microscopy of Bamboo fibrils hierarchy

After the chemical process, fibre bundles, single fibres, macro and microfibrils, nanofibrils aggregates, nanofibirls were obtained. The hierarchical structures of bamboo was observed as shown in Figure-9.

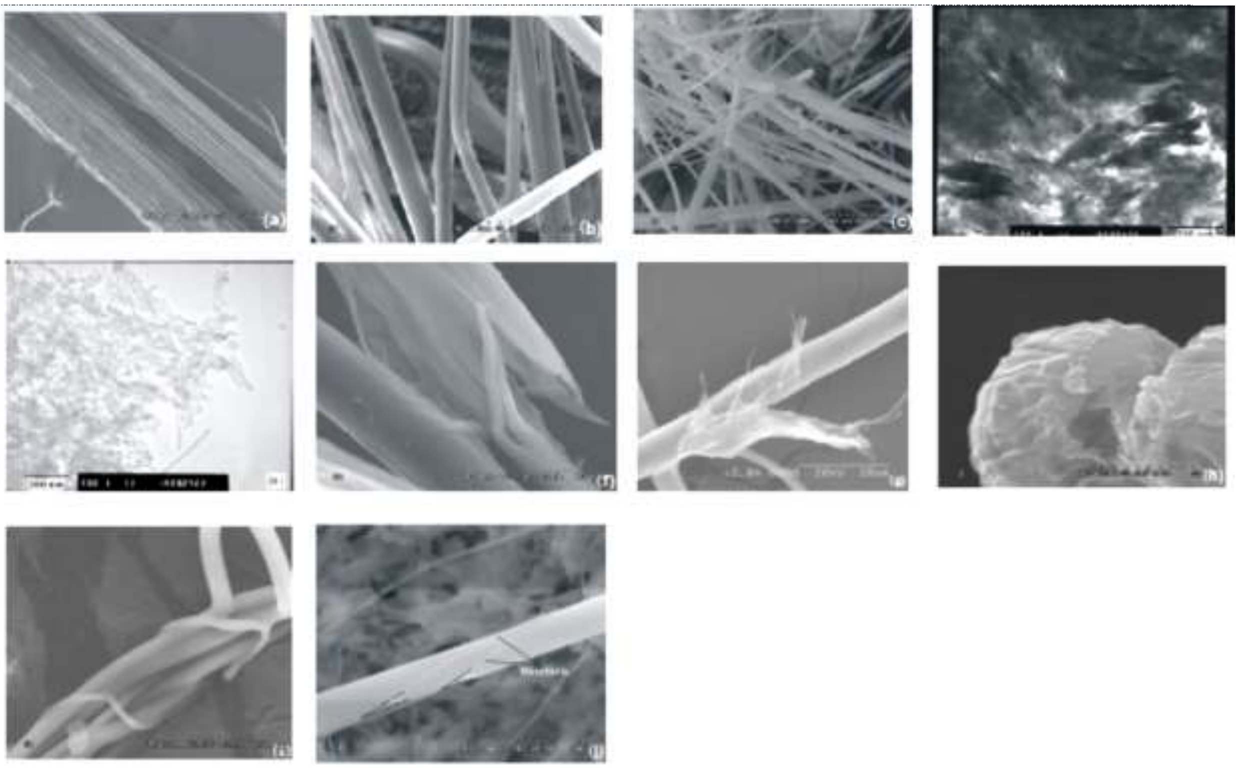


Figure-9. Bamboo fibrils and the hierarchical structures. (a) fibre bundles. (b) singlefibres. (c)macro and microfibrils. (d) nanofibrils aggregates. (e) nanofibrils. (f) a single bamboo fibre with broken tip. (g) hemicellulose and lignin composed membrane out layers of single bamboo fibre. (h) a broken fibre shows the inner fibrils and the outer layers. (i)binding structure of macrofibril. (j) microfibirls wrapped on the surface of a macrofibril [11] .

From the SEM pictures (Figure-9(a).), it can be seen that the single bamboo fibres with sharp tips are mostly well aligned in bundles. At the macro and micro fibril scale, however, the structure becomes complex. As shown in Figure-9 (f)-(h) the macrofibril bundles are surrounded by membrane layers composed of hemicellulose and lignin. Twining macrofirils (as shown in Figure-9(i) are also present in macro-scaled bundles as binders. Figure-9(j) shows the microfibrils are aligned at angles between 10 and 20 degree to the axis of the macrofibril form macrofibrils, Nanofibril aggregates are formed by overlapped single nanofibrils which, like single bamboo fibres, also have sharp tips[11].

3. PROCESS FLOW OF BAMBOO FIBRES

Morphological changes by micrograph observations show that an alkali treatment leads to an increase in fiber surface area available for interlocking adhesion with the matrix resin, resulting in superior interfacial bonding over untreated ones.

Fourier Transformation Infrared (FTIR) analysis confirms that removal of hemicellulose and lignin can increase the relative amount of cellulose content in the treated fibers. Furthermore, no new groups are introduced in the cellulose molecules after alkali treatment, as evidenced by spectra measurements.

Themogravetic analysis (TGA-DSC) testing reveals that surface treatment can influence chemical structure of bamboo fibers. Treated fibers exhibit higher thermal stability compared to untreated fibers, since the binding materials such as hemicellulose, pectin, and lignin can be diminished from the bamboo fibers by alkali reaction. Experimental results also suggest that hemicellulose is the most reactive constituent and is more easily degraded than the cellulose and lignin. Cellulose exhibits better thermal stability and lignin is degraded in a wide range of temperatures.The average fracture strength of treated fiber on the condition of 4 wt % NaOH for 1 h is increased by 10% compared to the untreated fibers. Alkali treatment can reduce the hydrophilicity of bamboo fiber, which might in turn improve the interfacial bonding. However,it is found from the standard deviations that the present concentration has a minor effect on the tensile strength of bamboo fibers[12].

4. DISCUSSION

Knowledge about fibre length and width is important for comparing different kinds of natural and wood fibres. A high aspect ratio (length/width) is very important in cellulose based fibre composites as it give an indication of possible strength properties. Changes in physical properties can be due to differences in fibre morphology. Major differences in structure such as density, cell wall thickness, length and diameter do result in differences in physical properties [13].

The anatomy of the culm is mainly composed of collateral vascular bundles embedded in parenchyma tissue. The size, shape, numbers and concentration of vascular bundles varies from the periphery towards the inner section of the culm, and from the base of the culm towards its apex. Close to the periphery, the vascular bundles are small, numerous and concentrated, while in the middle section of the culm they are larger and more widely spaced. In all bamboos, the size of the vascular bundles decreases noticeably from the base towards the apex with a corresponding increase in their density [4].

Elementary bamboo fiber wall possesses a unique multilayer configuration called polylamellate structure, where every layer is reinforced with cellulose microfibrils at different angles. This structure determines the mechanical properties of the technical fibers and contributes to the strength and modulus of the bamboo culm[14] The estimated Young's Modulus of the elementary fiber is 50 GPa for an aspect ratio (length/diameter) larger than 38. The orientation close to 0 degrees of the microfibrils of the secondary wall explains the high longitudinal stiffness of bamboo fibers. there is a good potential for long bamboo technical fibers as reinforcing material for polymeric matrices and that the material could be appropriate to be used for commercial applications[14]. The effects of age and height on mechanical properties are significant. With an exception of modulus of rapture (MOR), all the mechanical properties increase with age and culm height. The strength also increases with increase of density, amount of vascular bundles and fibre wall thickness [15].

5. CONCLUSION

The Morphology of the bamboo fibres macroscopic and microscopic structures are assessed. The macroscopic structures of the bamboo fibres are internodes, nodes, culms, technical fibres and elementary fibres. The microscopic structures of the bamboo fibres are cellulose, hemicellulose ,lignin and pectin. The diameter of the elementary fibre, technical fibre, the length of the technical fibre ,age of bamboo and the number of the technical fibres have affected the mechanical properties.. Bamboo fibres can be produced long and short fibre depending on the internodes and node length respectively. The helix angle of the fibres are affected the mechanical properties of the fibres if the helix angle is decreased, the mechanical strength would be increased. The diameter, length, tensile strength and young`s modulus of the bamboo culms are 6-11 cm, 23m, 237 MPa, 10 GPa and the diameter, length, tensile strength and young`s modulus of the technical fibres are 200-400µm, 20-34 cm, 800 MPa, 43 GPa and the diameter, length, tensile strength and young`s modulus of the elementary fibres are 12-20µm, 1-3 mm, 1150 MPa, and 50GPa respectively. The elementary fibres are the best mechanical strength and the lowest size in diameter and length from the type of bamboo fibres.

6. ACKNOWLEDGMENT

Researchers want to heartily thanks Dr. Tatek, Dean, School of Mechanical, Chemical and Materials Engineering and Mr. Abdulmelik H.Meda, program chair, Department of Mechanical Design and Manufacturing Engineering for their valuable inspiration, encouragement and providing necessary facilities for research.

REFERENCES

[1] Raymond Bosmans, University of Maryland Extension Specialist, Home and Garden Information center.
[2] ICCT BRIEFING, www.theicct.org,January 2013.

[3] J.M. Chard, G. Creech, D.A. Jesson, P.A. Smith. Green Composites: Sustainability And Mechanical Performance 18th International Conference On Composite Materials.
[4] Londoñoet al: (2002) Guaduaangustifolia Bamboo Science and Culture: The Journal of the American Bamboo Society 16(1): 1-8.
[5] RazakWahab et al: Relationship Between Physical, Anatomical And Strength Properties Of 3-Year-Old Cultivated Tropical Bamboo, VOL. 7, NO. 10, OCTOBER 2012 ISSN 1990-6145.
[6] Eduardo Trujillo, POLYMER COMPOSITE MATERIALS BASED ON BAMBOO FIBRES, Dissertation presented in partial fulfillment of the requirements for the degree of Doctor in Engineering.
[7] J. Fu et al. Bamboo fi bre processing: insights into hemicellulase and cellulase substrate accessibility, Biocatalysis and Biotransformation, January–February 2012; 30(1): 27–37.
[8] Osorio et al. In-depth study of the microstructure of bamboo fibres and their relation to the mechanical properties Journal of Reinforced Plastics and Composites 2018, Vol. 37(17) 1099–1113.
[9] Angel Pozo Morales , Alfredo Güemes , Antonio Fernandez-Lopez ,Veronica Carcelen Valero and Sonia De La Rosa Llano Bamboo–Polylactic Acid (PLA) Composite Material for Structural Applications Materials 2017, 10, 1286; doi:10.3390/ma10111286.
[10] Dagang Liu • Jianwei Song • Debbie P. Anderson •Peter R. Chang • Yan Hua Bamboo fiber and its reinforced composites:structure and properties Cellulose (2012) 19:1449–1480 DOI 10.1007/s10570-012-9741-1.
[11] Y.Q. Wan and F. K. Kohierarchical structure and Mechanical properties of bamboo fibrils.
[12] Xiaoping Zhang, Fang Wang ,* and Leon M. Keer, Influence of Surface Modification on the Microstructure and Thermo-Mechanical Properties of Bamboo Fibers, Materials 2015, 8, 6597–6608; doi:10.3390/ma8105327, www.mdpi.com/journal/materials.
[13] A.K. Bledzki, V.E. Sperber and O. Faruk, Natural and Wood Fibre Reinforcement in Polymers ISBN 1-85957-359-2.
[14] Osorio et al: A Complete Microstructure And Mechanical Characterization Of Bamboo Technical And Elementary Fibers,The 19th International Conference On Composite Materials
[15] Abd. Latif Mohmod et al: Effects Of Anatomical Characteristics On The Physical And Mechanical properties Of BambusaBlumeana, Journal of Tropical Forest Science, Vol. 6, No. 2 (December 1993), pp. 159-170.

CITE AN ARTICLE

Dessalegn, Y., & Singh, B. (2019). EFFECT OF ANALYSIS ON MORPHOLOGY OF BAMBOO FIBER: A REVIEW. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY,8*(3), 7-17.