A REVIEW ON THE EFFECT OF HUMIDITY & ITS PREVENTION UPON BAMBOO FIBER GREEN COMPOSITES.

Nabanita Banik[1], G.R.K.Sastry[2],Vidyut Dey[3]
Production Engineering Department, NIT Agartala,
Jiranaia-799046, India.
[1]nabanita.banik@gmail.com, Phn: +919436473634
[2]grksastry1@rediffmail.com, Phn: +918730996374
[3]vidyutdey@gmail.com, Phn: +919862227751

Abstract- Biodegradable green composites made from natural fibers offer a potential & commercial alternative to the petroleum based composite materials. Though they are biodegradable & ecofriendly, range of application of these materials is limited due to their poor mechanical properties such as strength, stiffness, & wear resistance. The most influential factors that control the properties of the green composites are processing conditions, processing techniques, fiber/matrix interface & moisture absorption capability of natural fiber. Hence proper control of these factors can make the developed composite more efficient & flexible to different kinds of applications. This paper represents a patulous overview of the natural, green, ecofriendly bamboo fiber composite related problems due to the contact of humidity & its solution.

Keywords- fiber/matrix interface, moisture effect on bamboo fiber, lignin identification, lignin measurement, delilignification

1. Introduction

Fiber reinforced polymer composites are one of the costly materials, because of their high specific strength, extreme versatility & low cost. From the In addition to that, bio composites diminish the usage of alarmingly depleting fossil fuels & CO_2 emission.

1.1.1 Biodegradable polymers [biopolymers]

Due to disposal problems, diminishing fossil fuels & global environmental consciousness it is necessary to replace the use of petroleum based products by the eco-friendly & sustainable materials such as synthetic past decades it has been shown that fiber reinforced plastics using range belongs from aerospace applications to furniture. In general these materials are composed of synthetic fibers, petroleum based thermoset & thermoplastic polymers. The backside of these composites is that, they never degrade nor disposable after their intended life cycle & may cause a serious global environmental problem & emissions during calcination. One of the most sought after approach to overcome this drawback is to recycle the fabricated composites but the recycling is more expensive & difficult. So, it is preferable to define the problem may cause in between the composites & try to dissolve it.

1.1 Green composites

Due to disposal problems, diminishing fossil fuels & global environmental consciousness it is necessary to replace the use of petroleum based products by the eco-friendly & sustainable materials such as synthetic fibers with natural fibers. Green composites are also referred as bio composites. In bio composites synthetic fibers & petroleum based polymers are replaced with natural fibers & biodegradable polymers derived from renewable resources respectively.

fibers with natural fibers. Green composites are also referred as bio composites. In bio composites synthetic fibers & petroleum based polymers are replaced with natural fibers & biodegradable polymers derived from renewable resources respectively. In addition to that, bio composites diminish the usage of alarmingly depleting fossil fuels & CO_2 emission

1.1.2 Natural fibers

Although glass fiber is a prominent conventional composite, due to their high production cost, natural fibers get easy accessible chance to replace themselves with the potential & economical advantages such as renewable character, low cost, low density, specific strength, CO_2 isolation & of course biodegradability. Another big reason to use natural fiber is that, the energy required for producing natural fiber mat is approximately 17% of the energy required to produce a glass fiber mat [7], whereas the mechanical properties of natural fibers are almost similar to that of the glass fibers. Not withstand natural fibers such as flax, jute, hemp, bamboo, & sisal are widely used natural fibers in composite materials due to their superior properties & availability, as well as they can be also used as reinforcement or fillers. The composition of natural fiber consists of lignin, rigid cellulose act as matrix & cellulose micro fibrils act as reinforcement.

1.2 Fiber/Matrix Interface

As the strength, modulus & toughness of the composites confides heavily on the fiber/matrix adhesion, the interface in-between them is significantly attach to each other where the chemical & mechanical bonding in between them should be fair as it is essential for effective transfer of fiber load through shear stress from matrix to fiber. Poor adhesion at the interface cannot exploit the capabilities of the reinforcements to their full extent. As the natural fibers are hydrophilic & polar in nature, they should be attached with the biodegradable polymers because of their hydrophobic & nonpolar nature. Combination of both relies as good fiber/matrix interface & improves the mechanical properties but the chances of occurring moisture & micro cracks in between the final product is always remain as the natural fibers have early & late high moisture absorption tendency. Regarding this point of view it is necessary to stop the moisture insertion tendency from the very beginning of the work by inoculation any chemical treatment or by any other processing methods.

2.1 Moisture Absorption

Eminent trend of moisture absorption by the natural fiber is the biggest factor that limits the bio composites in engineering applications & hinders the final product utilization. Outpouring of bio composites at a humid condition conducts swelling which is the reason of happening micro cracks in the matrix. Percolation of Moisture into the decay of fiber/matrix adhesion alleviates mechanical properties & dimensional stability of the product made from the fibers.

Before using the bio composites in commercial field it is necessary to be worthy as a broad acceptance of these materials in all over the world & for this it is necessary to define the restriction methods of moisture penetration as well as also how to remove it from the final product. It is better if the moisture penetration can be stopped at the beginning. Exertion of the present work is that to conquer the above mentioned limitations through bamboo fibers & to promote the bio composites with an ultimate intention of amplifying the range of applicability of these composites.

3.1 Bamboo Fiber

Bamboo fiber is one the most common & extensively cultivated natural, green, eco-friendly & regenerated cellulose fiber in with the ability of 100% biodegradable in soil by microorganisms & sunshine. The cell structure of bamboo fiber is shown in fig.1. The cell wall of the fiber is made up of a primary wall & secondary wall. The secondary wall is made up of various constituents consisting various amounts of cellulose, hemicelluloses, polysaccharide & pectin. Each & every fibers are bonded together by a lignin-rich region known as middle lamella related to the primary cell wall zone & consisting above 90% of lignin.

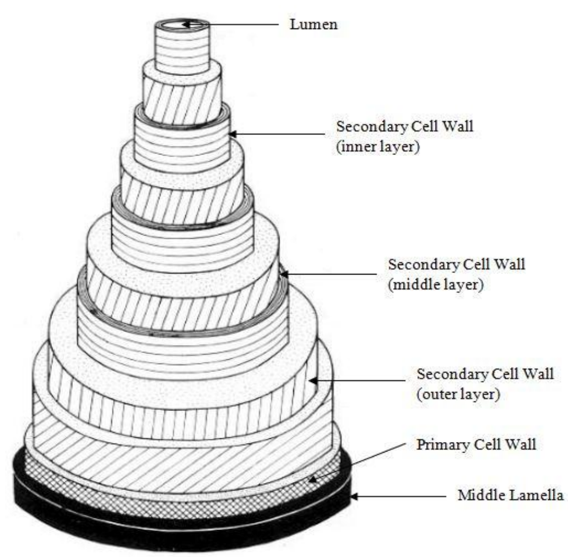


Fig.1: Cell structure of bamboo fiber

3.1.1 Constituents belong in the cell walls of bamboo fibers

Lignin is the primary constituent of bamboo fiber in the formation of cell walls between cellulose, hemicelluloses & pectin components, due to its flexibility and decomposes property. Lignin is a complex cross-linked phenolic polymer with a

n amorphous structure made up of phenyl propane (C9) units [9]. As lignin is more hydrophobic & it has the most affinity with water it plays the vital role in prosecution of water for vascular tissues in bamboo stems.

Cellulose, a linear condensation polymer consisting of D-anhydro-glucopyranose units joined together by β-1, 4-glucosidic bond [6] is the important structural component of bamboo fiber. Cellulose are linked together in bamboo fiber named microfibrils.

Hemicellulose, the group of polysaccharides bonded together is circumstantially associated for embedding the cellulose microfibrils in a matrix. They are hydrophilic, branched & having lower molecular mass.

3.2 Effect of lignin & water affinity upon bamboo fiber

3.2.1 Shrinkage & swelling

Bamboo changes its dimension when it loses or gains moisture. Moisture is the number one enemy of bamboo and prolonged exposure will eventually weaken the material. Bamboo is a hygroscopic material, thus the moisture content changes with the changes in the relative humidity and temperature of the surrounding environment. Dimensional stability is very crucial in structural composite products because the safety and comfort in a structure usually depends on them. As it starts to loose moisture, it will shrink or swell only below the fiber saturation point (FSP). The FSP of bamboo is reached when bamboo loses its free water and the cell wall is saturated with bound water [4]. The shrinkage occurs in proportion to the amount of water loss from the cell wall & the intromit of water molecules into the cell wall results in swelling. Shrinkage & swelling percentage can be measure in this way [4]:

decrease dimension (V,L,R or T)original dimension x 100

increase dimension (V,L,R or T)original dimension x 100

Where,

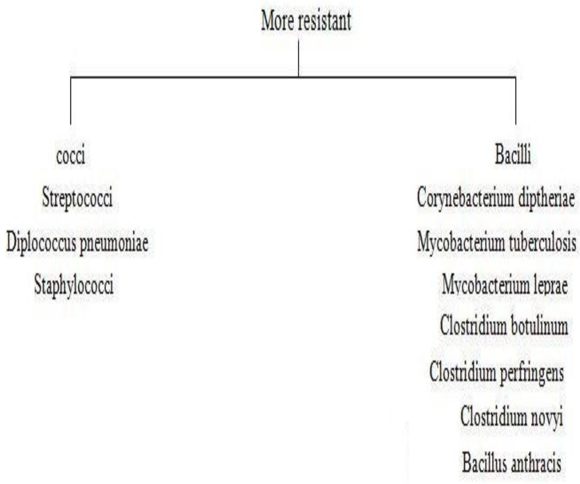
V, L, R & T are defined as volume, longitudinal, radial & tangential direction of shrinkage & swelling of bamboo fiber.

3.2.2 Pathogenic fungi & bacteria due to the contact of humid condition

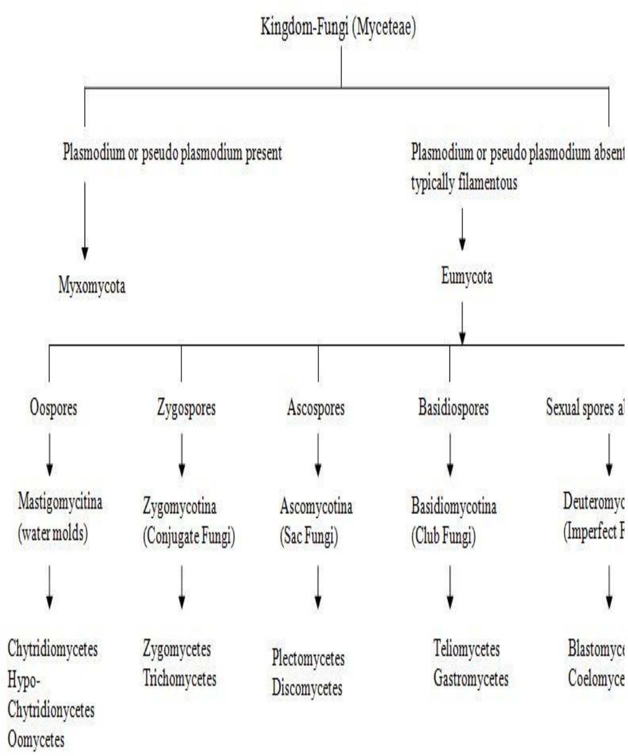
As lignin is hydrophobic & always has the tendency of moisture absorption so there is a prominent chance of taking place of fungi enzymes as well as pathogenic bacteria also may occur. Here probable chances of the fungi & bacteria have mentioned below [12].

3.2.2.1 Some Characteristics of Gram-positive & Gram-negative bacteria & examples of some important pathogenic bacteria belonging to the two groups.

Characteristics	Gram-positive	Gram-negative
Gram's reaction (microscopic appearance)	Dark-violet or purple	Red or brown
Cell wall composition	Low in lipids (1-4%)	High in lipids (11-22%)
Susceptibility to penicillin	More susceptible	Less susceptible
Effect of basic dyes(e.g. crystal violet)	Marked inhibition	Less inhibition
Resistance to physical disruption	More resistant	Less resistant



3.2.2.2 Outline characteristics of Fungi (based on Ainsworth, 1973):



To avoid the shrinkage & swelling loss it is necessary to identify, measure & remove the lignin thus the probable chances of damage due to lignin may reduce.

4.1 Methods to identify lignin [1, 2, 10]:

Name of the Method	Chemical or other process used in the method	Advantage
Indirect method	Cl or $KMnO_4$ is used as the oxidant. Later modified by the use of Na & $Ca(ClO)_2$. The lignin deduction amount is measured by the chlorine consumed amount based on the titration.	Willingly influential depletion of oxidants than polysaccharides
Noninvasive method	(i) Infrared spectroscopy technique for distinguish phenolic insoluble lignin in cell wall samples.	Instinctive comparing in between samples with ordaining structural & compositional similarities as well as dissimilarities.
	(ii) Near infrared spectroscopy (NIRS) technique for quantifying lignin	Deliberation of the concentration of the plant components such as fats, oils, protein, total fiber, etc. by which differentiation of lignin amount is quite easy.
	(iii) Nuclear magnetic resonance (NMR) technique	Provides circumstantial characterization of composition & structured features of lignin also in soluble conditions.
Direct Method	(i) Klason method or 72% H_2SO_4 acid procedure with distilled water.	Easy quantification of lignin just by cooling & drying.
	(ii) Ellis pre-extraction method with ethanol-benzene pursued by a proteolytic enzyme treatment.	Get-at-able procedure to obtain acid insoluble lignin residue for immature fibers obtaining high protein samples.
	(iii) Goering & Van Soest or acid detergent (AD) extraction method	For evacuating potentially contaminating substances from the lignin residue.
Tappi method (UM-250)	UV absorption technique & Fourier transform infrared spectroscopy (FTIR)	Specify characteristics of chemical groups in acid insoluble lignin & standardise their utility.

4.1.1 Measurement procedure of lignin [13, 15]:

(i) Acid-insoluble lignin can be measured in this way (KLASON METHOD):

% acid-insoluble lignin

[illegible] x100%

[illegible] % x100%

Where,

W_1 = initial sample weight

W_2 = weight of the crucible, acid-insoluble lignin, & including acid-insoluble ash

W_3 = weight of the crucible & including acid-insoluble ash

$T_{initial}$ = % of total solid contents present on the sample at the initial stage

T_{prep} = % of total solid contents present on the sample during preparation for analysis

T_{final} = % of total solid contents of the prepared sample used till the end of lignin analysis

(ii) Acid-insoluble lignin can be measured in this way (TAPPI METHOD UM-250):

% acid-soluble lignin

Ab x a x df x V x L1000 mlW x Tfinal 100

x100

Where,

A = absorbance at 205 nm , df = dilution factor, b = cell path length 1 cm

a = absorptivity, V = filtrate volume, W = initial sample weight

$\%T_{final}$ = % of total solid contents of the sample after extraction

4.2 Delignification:

Here some of the delignification oxidants have mentioned below:

Oxidants	Form	Advantage	Disadvantage
Chlorine	Gas	Effective, economical delignification. Good practical removal	Can cause loss of medullary strength if used improperly, organic chlorine formation.
Hypochlorite	$Ca(OCl)_2$, NaOCl solution 40 g/l as Cl_2	Get-at-able to make & use	Can cause loss of medullary strength if used improperly, chloroform formation
Chlorine dioxide	7-10 g/l ClO_2 solution in water	Achieves high brightness without pulp degradation, good particle removal.	Must be made on site. Expensive, some organic chlorine formation
Oxygen	Gas used with NaOH solution	Low chemical cost, provides chloride-free effluent from recovery	Used in large amounts requires expensive equipment. Can cause loss of medullary strength
Hydrogen peroxide	2-5% solution	Easy to use, low capital cost	poor particle bleaching.
Ozone	Gas in low concentration in oxygen	Effective, provides chloride free effluent for recovery	Expensive, degrades pulp, poor particle bleaching
Reductant Hydrosulfite (for mechanical pulps only)	Solution of $Na_2S_2O_4$ or made onsite from $NaBH_4$ solution plus SO_2	Easy to use, low capital cost.	Decomposes readily. Limited brightness gain
Alkali Sodium Hydroxide	5-10% NaOH solution	Effective and economical	Darkens pulp

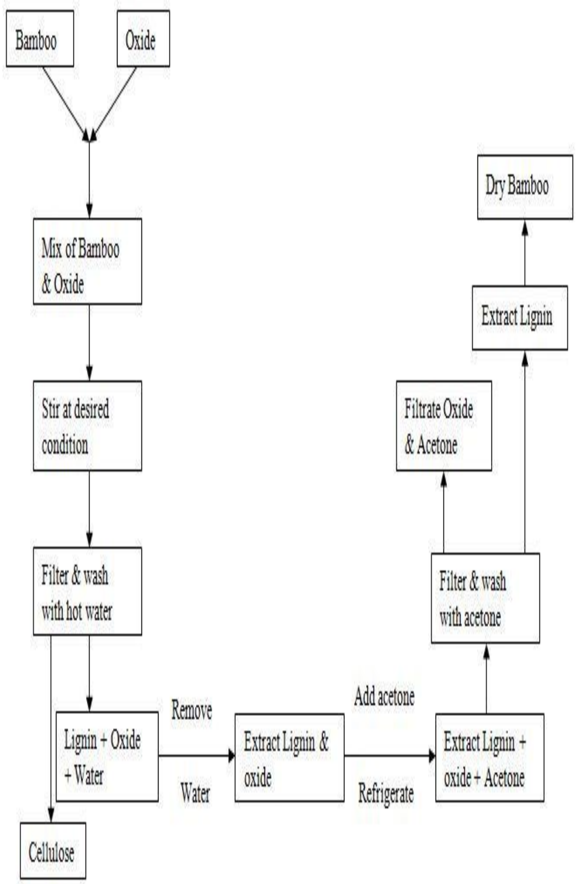


Fig.2 : Experimental scheme for extracting bamboo lignin

Conclusion:

Renewable resource & biodegradable Plant fibers are eco-friendly since they do not return excess CO_2 into the atmosphere when they are composted. This particular property of plant fibers is the evidence of the presence of their biocomponents which include cellulose, hemicellulose and lignin which have the necessary functional groups that can enable micro-organisms to degrade them easily [8]. From the previous survey it has been shown that fungal treatment makes a chemical change in lignin, which is quite helpful to remove the lignin easily in the subsequent bleaching stages without changing the strength properties of the fiber. For using the lignocellulosic materials a deep concern have to put on the lignin content. With providing compressive strength & stiffness in the cell wall of the fibres lignin protects the carbohydrates from chemical and physical damage [12]. In natural fibre reinforced composite, lignin provides flexibility but in the latter-day applications, lignin affects hydrolysis and would require extensive and expensive delignification if present in large amounts. Lignocellulosic materials with low lignin and high cellulose contents are suitable for pulp making, textile, flooring, decoration and bioethanol production.

References:

1. Simplified determination of lignin content in hard & soft woods via UV- spectrophotometric analysis of biomass dissolved in ionic liquids: Lindsey M. Kline, Doglus G. Hayes, Alvin R. Womac, and Nicole Labbe.

2. Can lignin be accurately measured?: Ronald Hatfield & Romualdo S. Fukushima, March 28, 2005

3. Conversion of bamboo to sugars by dilute acid & enzymatic hydrolisis: Nakorn Tippayawong, Nuttida Chanhom; 4.8.11

4. Forest products & wood science. An introduction, lowa state University Press/Ames. Third Edition: Haygreen, J.G, & J. L. Bowyer, 1998.

5. Mechanical properties of biodergradable composite from polylactic acid (PLA) & microctrystalline cellulose (MCC) : A. P. Mathew, K. Oksman & M. Sain, Journal of applied polymer science, pp. 2014-2025

6. Review of current international research into cellulosic fibers & composites: S. J. Eichhorn, C.A. Baillie, N. Zafeiropoulos, l.Y. Mwaikambo, M.P. Ansell, A. Dufresne, K.M entwistle, P.J. Herrea-Franco, G.C.Escamilla, L. Groom, M. Hughes, C. Hill, T.G. Rials & P.M. Wild; Journal of material science & technology, pp. 2107-2131.

7. Recent advances in the application of natural fiber based composites: J. K. Pandey, S. H. Ahn, C. S. Lee, A. K. Mohanty & M. Misra; Macromolecular Materials & Engineering, pp. 295, 2010, 975-989.

8. Natural fiber polymer composites: A review. Adv. Polym. Tech 18: 351-363; saheb, n.D. & Jog, J. P.,(1999)

9. Wood & cellulosic chemistry, 2nd edition, Marcel Dekker, NewYork, 2001: D.N.S. Hon & N. Siraishi.

10. Methods to reveal the structure of lignin by Prof. Dr. Gosta Brunow

11. Physico-chemical characterization of lignocellulosic fiber from Ampelocissus cavicaulis:

Agu C.V., Njoku O.U., Chilaka F.C, Okrie S.A., Agbiogwu D

12. Experiments in microbiology, plant pathology & Biotechnology by K.R Aneja, New age international publishers, Fourth edition, pp. 100-103, 287, 454

13. Determination of acid-insoluble lignin in biomass: David Templaton & Tina Ehrman; Chemical analysis & testing task, Laboratory analytical procedure, LAP-003, 19th Jan,95.

14. Enzymatic biodegradation of lignin-cellulose complex in plant origin material: Regina Vernaite, Vita Raudoniene, Dangoule Bridziuviene; ISSN 1392-1320 MATERIAL SCIENCE (MEDZIAGOTYRA). Vol. 17, No. 1. 2011

15. Determination of acid-soluble lignin in biomass: Tina Ehrman; Chemical analysis & testing task, Laboratory analytical procedure, LAP-004, 9th Sept,96.

16. SAIMAA UNIVERSITY OF APPLIED SCIENCES, Faculty of Technology, Imatra, Paper Technology