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Investigation on Moisture Absorption Behavior of Chemically Treated Natural Fiber Reinforced Hybrid Polymer Composites

[1]Debasmita Pani, [2]Punyapriya Mishra*

[1] Research Scholar, Department of Mechanical Engineering, Veer Surendra Sai University of Technology, [2]Associate Professor, Department of Mechanical Engineering, Veer Surendra Sai University of Technology, Burla, Odisha-768018, India.

Abstract

In the present study hybrid polymer reinforced composites were fabricated from luffa fiber, bagasse and coir dust reinforced in epoxy matrix. The moisture absorption behavior of the developed composites were studied at different environmental conditions viz. (i) steam treatment at 100^0C, (ii) subzero treatment at -23^0C, (iii) saline treatment in NaOH solution. The amount of moisture absorption and weight change was determined and co-related with the mechanical degradation. The fractured surfaces were analyzed under Scanning Electron Microscope (SEM).

Keywords: - Natural fiber hybrid composite, Luffa, bagasse, coir, chemical treatment, weathering behavior.

I. INTRODUCTION

Growing need for energy efficient and environment compatible processes and products have triggered a fundamental change towards designing of newer and innovative materials. Biofibres, derived from renewable plant sources are increasingly being used as reinforcing materials in both thermoplastic and thermoset matrix composites which provide added advantage of ultimate disposability and raw material utilization [1] as well as high specific strength and modulus. The different

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[*] **Corresponding author. Dr. Punyapriya Mishra, Associate Professor, Dept. of Mechanical Engg., Burla, Odisha. E-mail: priya.punya@gmail.com.*

thermoplastics and thermosetting Resins used offer a number of advantages such as low density, good corrosion resistance, low thermal conductivity, low electrical conductivity, translucence, and aesthetic color effects. Its limitations include low transverse strength, low operational temperature limits [2]. Epoxy resins have more number of 1, 2- epoxide groups per molecule which helps in cross-linking of polymers by introducing curatives that react with epoxy and hydroxyl groups situated on adjacent chains.

Natural fibers offer several advantages of low density, low cost, abundant availability, biodegradability, incineration, etc. Cellulose-based natural fibres can be potentially utilized as reinforcing materials especially in developing tropical nations where these fibres are abundantly available. However, natural fibers composites have the main disadvantage of poor compatibility between fiber and matrix and have relative high moisture absorption rate [3]. This is because natural fibers components include cellulose, hemicellulose, lignin, pectin, waxes and some water soluble substances. Cellulose is a semi crystalline polysaccharide made up of D- glucopyranose units linked together by β-(1-4)-gluco- sidic bonds [4]. Large amount of these hydroxyl groups in cellulose gives the natural fiber hydrophilic properties. When hydrophobic matrices are used with these fibers there is a very poor interface and poor resistance to moisture absorption [5]. Hemicellulose has a branched structure, is amorphous and has significantly lower molecular weight than cellulose. It is strongly bound to cellulose fibrils by hydrogen bonds. Because of its open structure hemi cellulosic polymers contain many hydroxyl and acetyl groups which makes it partly soluble in water and hygroscopic [6]. Lignin is a very complex amorphous compound mainly constituted of aromatic polymers of phenylpropane units though they have minimal water sorption property. Therefore, to combat interface incompatibility as well as moisture absorption problems, chemical treatments or coupling agents are employed.

In the present paper, an attempt has been made to chemically modify the interface of natural fibers for better interface bonding with the matrix material. And also the effect of different environmental conditions on the moisture absorption behaviour of composite samples have been studied and co-related with SEM micrographs.

II. EXPERIMENTAL

2.1 Material Requirements

A. Natural Fibers

Luffa cylindrica, bagasse, coir

B. Chemicals

Epoxy LY556, Hardener HY951, NaOH.

2.2 Collection of Fiber

A. Luffa

Fully ripened and dried fruits of Luffa cylindrica were collected locally from western Odisha region where they are quite abundantly found. After removal of the skin, its outer core was cut and gathered to be used as the fiber source.

B. Bagasse

Bagasse fiber was obtained from sugarcane after extraction of juice. The outer rind of the fibers was collected while the inner pith was rejected. The fibers were cut at lengths greater than their critical length of 3.62mm [7] for its use as short fibers.

C. Coir

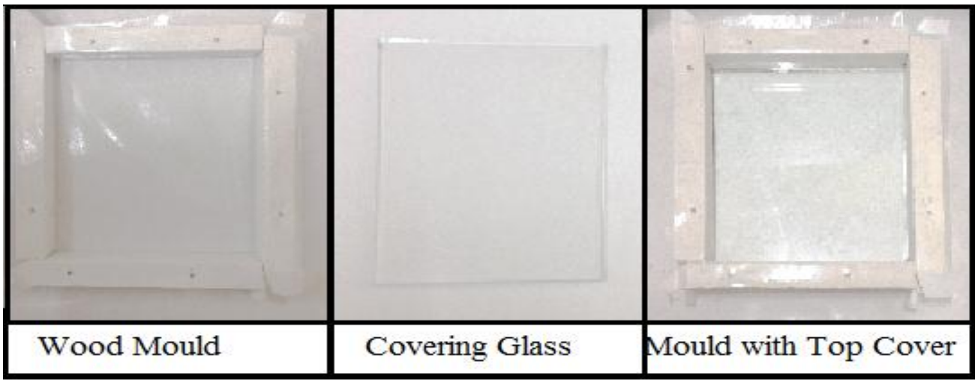
Coir dust was collected from the outer fiber cover on the hard shell of dried coconut. It was collected so as to be used as a particulate reinforcement.

2.3 Chemical Treatment

In the present study the fibers were soaked with 5ml% of NaOH solution for 4hours with a fiber to liquor ratio of 1:15. This treatment is known as alkali treatment/ mercerization treatment. Thereafter the treated fibers were washed with huge quantities of distilled water till a neutral pH was obtained. The fibers were first dried for 48 hours in open air then in an oven at 60^0C for 6 hours.

2.4 Preparation of Mould

Wooden moulds were prepared with inner dimension of (14X12X4) cm^3 and were firmly fixed over a board. The mould walls and base were properly covered with silicon paper. Figure 1 represents the mould prepared for fabrication of composites.



Wood Mould

Covering Glass

Mould with Top Cover

Figure 1. Wooden Mold

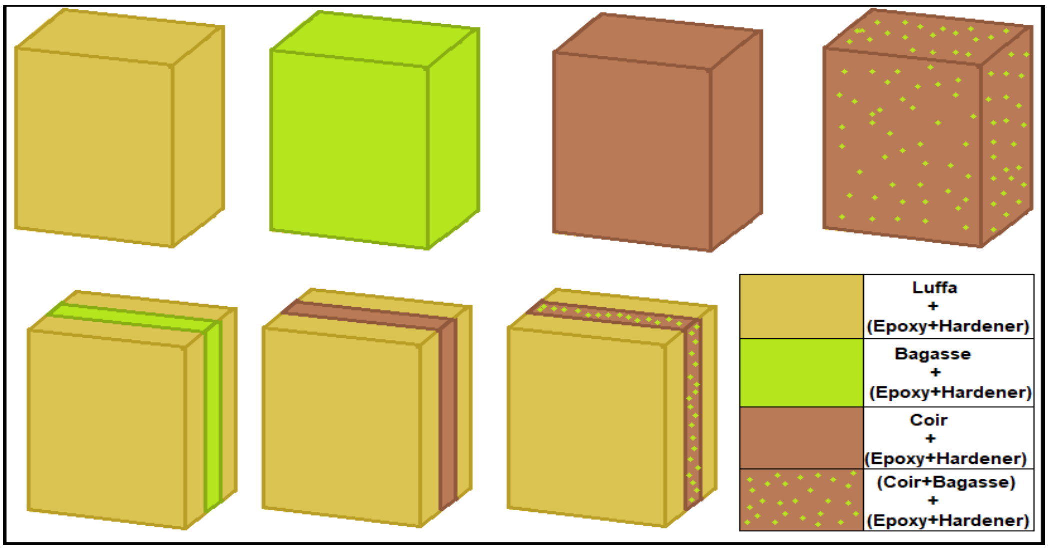


Figure 2. Schematic diagram of composites

2.5 Fabrication of composites

Composites slabs were fabricated by hand lay-up technique. Epoxy resin (LY556) was mixed with hardener (HY 951) in ratio of 10:1. Then the chemically treated fibers were added and well mixed with it till all air bubbles escaped. The mould was then sprayed with silicon spray to aid easy removal of the composite after fabrication. The mixture was then poured into the mould. Curing of composite samples take a period of 24-48 hours at room temperature. After it is cured the mold is broken and the fabricated composite taken out. Figure 2 represents schematic diagram of the fabricated composites.

The list of fabricated composites are as follows:

a. L- Luffa single mat reinforced composite
b. B- Bagasse 20wt% reinforced composite
c. C- Coir dust 10wt% reinforced composite
d. CB- Coir dust 5wt% and bagasse 5wt% reinforced hybrid composite
e. LBL- Bagasse 10wt% sandwiched between two luffa fiber mat reinforced hybrid composite
f. LCL- Coir 10wt% sandwiched between two luffa fiber mat reinforced hybrid composite
g. L(CB)L- Coir 5wt% and Bagasse 5wt% sandwiched between two luffa fiber mat reinforced hybrid composite.

The selection of percentage of different fibers for composite samples is based on optimum strength condition.

2.6 Study of Environmental effect

The fabricated composite samples were exposed to different environmental conditions like steam, saline and subzero and their effects on moisture absorption behavior were studied by monitoring the weight changes at time interval of 8hrs and upto 64hrs.

III. RESULTS AND DISCUSSION

3.1 Weathering Behavior

Apart from different minerals and many other components, primary components, as the natural fibers include cellulose, hemicelluloses, lignin, pectin, waxes and several water soluble substances, these are hydrophilic in nature due to presence of large amount of hydroxyl group in cellulose. Therefore the moisture absorption behavior is an important parameter to be studied.

3.1.1 Steam Treatment

Initially upon exposure between 0 to 48 hours there is greater change in weight due to higher rate of moisture absorption. After 48 hours of exposure it becomes stable (Figure 3). This may be due to high moisture absorption and swelling of fibers at such a high temperature of above 100°C which became stabilized after attaining a saturated moisture absorption point in time span of 48 hrs resulting in very less weight change (Figure 4).

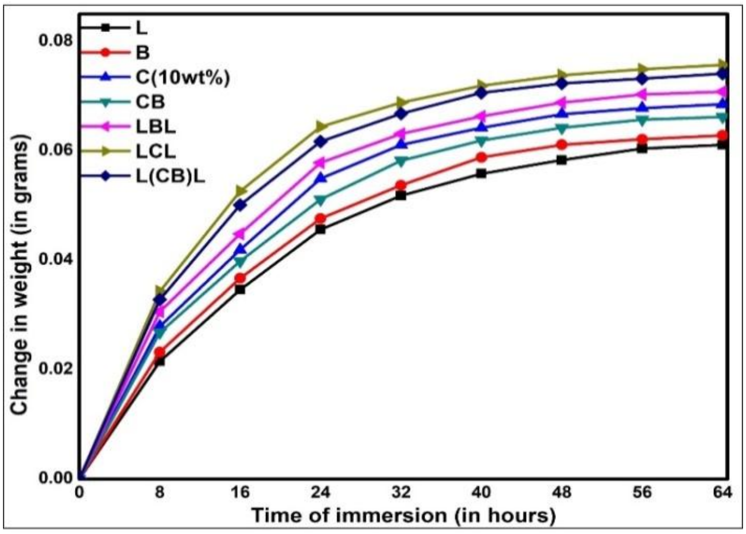


Figure 3. Change in weight after steam treatment

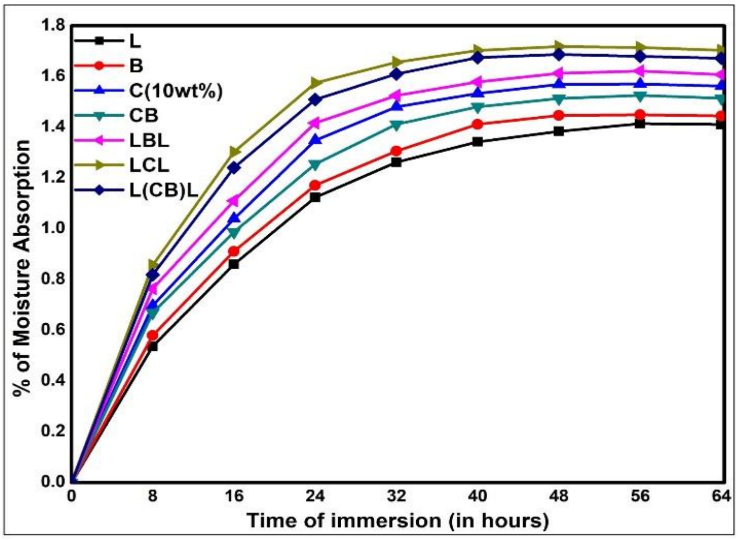


Figure 4. Percentage of moisture absorption after steam treatment

3.1.2 Subzero Treatment

Figure 5 and 6 represents the change in weight and percentage of moisture absorption of the various composite samples with different time of immersion. Upon exposure to subzero environment, initially weight change of composites increases from 0 to 48 hours at a higher rate. This may be due to less intermolecular hydrogen bonding which leads to higher amount of moisture absorption. After 56 hours of exposure, the weight change and percentage of moisture absorption behavior becomes stable due to saturation in absorbing capacity.

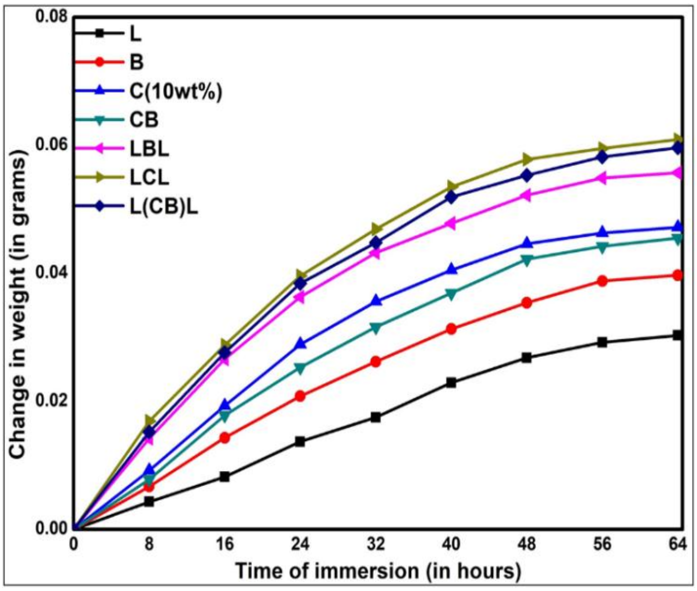


Figure 5. Change in weight after subzero treatment

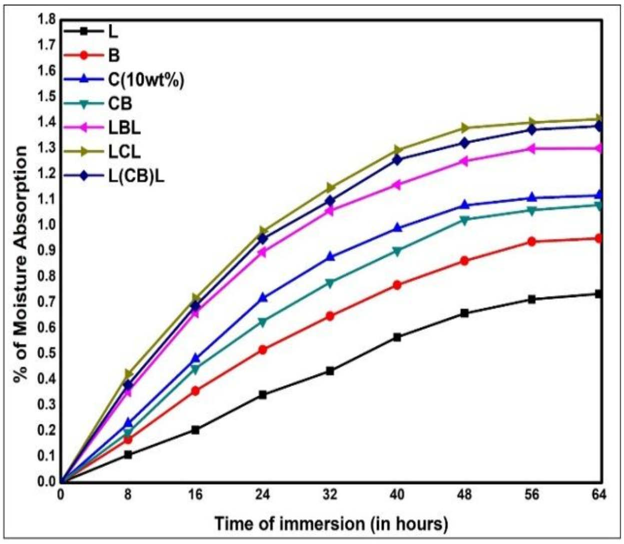


Figure 6. Percentage of moisture absorption after subzero treatment

3.1.3 Saline Treatment

In case of saline treatment between 0 to 48 hours, different composites depict a high rate of weight gain pattern which decreases after 48 hours of exposure. Then its weight change and moisture absorption pattern becomes stable (figure 7 & 8). The difference in moisture absorption behavior is may be due to the transport of water molecules and low compatibility of the hydrophobic polymers [8]. Even after chemical modification of the fibers, with increase of fiber content, the amount of moisture absorption increases.

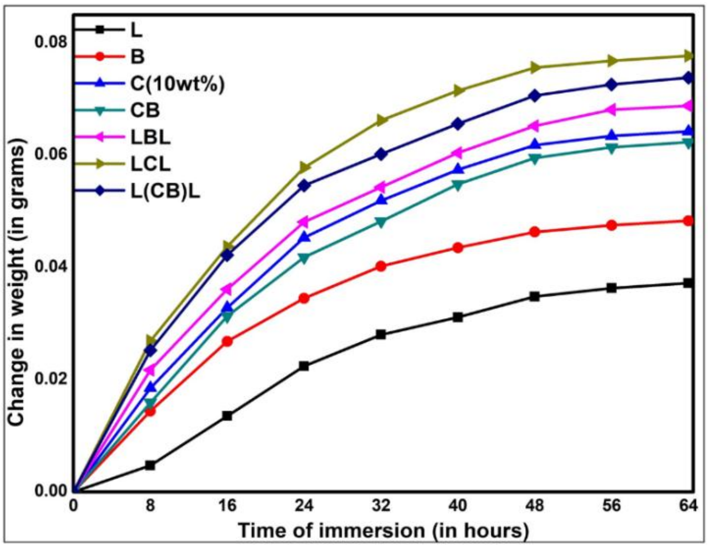


Figure 7. Change in weight after saline treatment

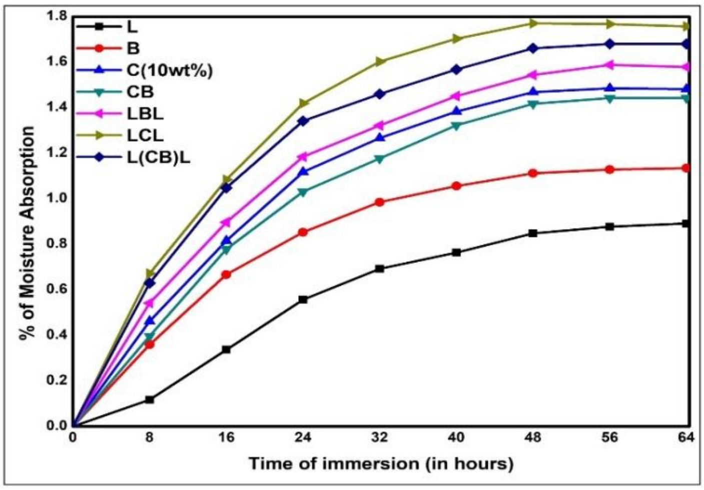


Figure 8. Percentage of moisture absorption after saline treatment

The coefficient of diffusion, for each specimen was determined from the maximum percent of moisture uptake shown in table 1 to 3.

Table 1: Diffusivity Index of Composite Samples under Steam Treatment

Type of Composite	**Max moisture content, M(m) (in gram)**	**Thickness, h (in mm)**	**Slope, k**	**Diffusivity** $D=\pi*[(kh/4M(m))^2]$
L	0.389	6.35	0.190	1.892
B	0.406	6.45	0.204	2.074
C	0.453	6.50	0.246	2.462
CB	0.433	6.60	0.237	2.557
LBL	0.472	6.75	0.270	2.939
LCL	0.516	6.80	0.303	3.134
L(CB)L	0.501	6.85	0.290	3.079

Table 2: Diffusivity Index of Composite Samples under Subzero Treatment

Type of Composite	**Max moisture content, M(m) (in gram)**	**Thickness, h (in mm)**	**Slope, k**	**Diffusivity** $D=\pi*[(kh/4M(m))^2]$
L	0.152	6.35	0.037	0.482
B	0.213	6.45	0.058	0.623
C	0.271	6.50	0.081	0.754
CB	0.251	6.60	0.068	0.635
LBL	0.330	6.75	0.125	1.279
LCL	0.363	6.80	0.149	1.524
L(CB)L	0.351	6.85	0.134	1.356

Table 3: Diffusivity Index of Composite Samples under Saline Treatment

Type of Composite	**Max moisture content, M(m) (in gram)**	**Thickness, h (in mm)**	**Slope, k**	**Diffusivity $D=\pi*[(kh/4M(m))^2]$**
L	0.208	6.35	0.042	0.330
B	0.301	6.45	0.127	1.455
C	0.395	6.5	0.163	1.411
CB	0.375	6.6	0.140	1.198
LBL	0.422	6.75	0.191	1.832
LCL	0.496	6.8	0.238	2.094
L(CB)L	0.464	6.85	0.223	2.126

3.2 SEM Analysis

The micrographs of fractured surface of different composites exposed to different environmental conditions are shown in the figures 9-11 for steam, subzero and saline environmental conditions respectively.

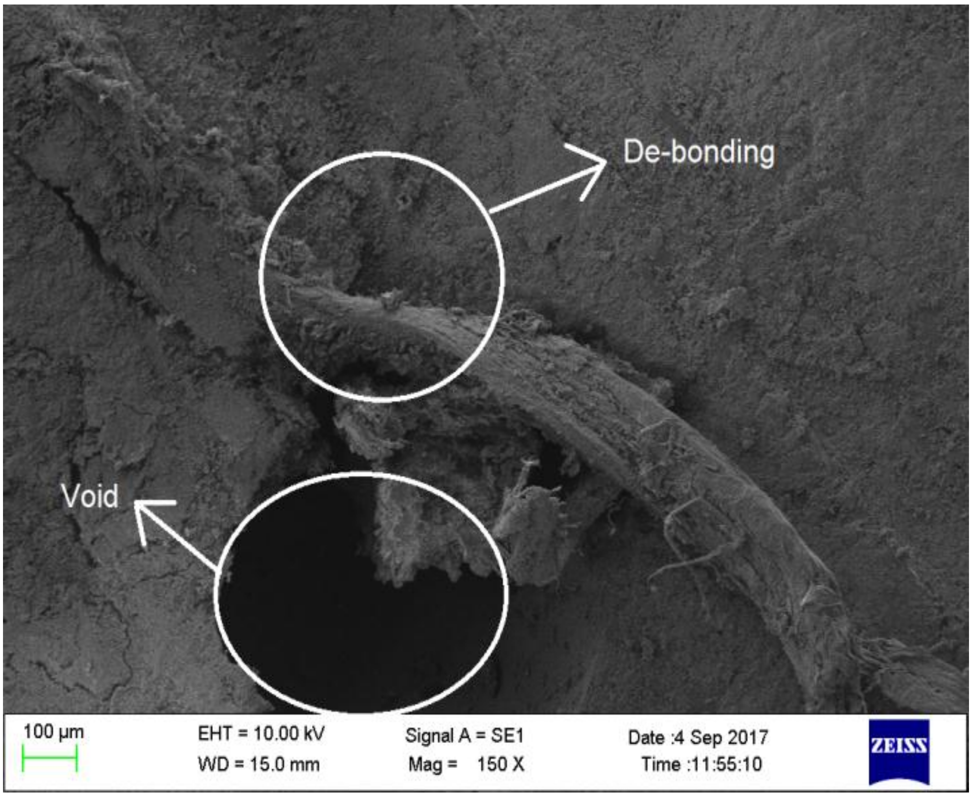


Figure 9. Micrograph of LCL after steam treatment

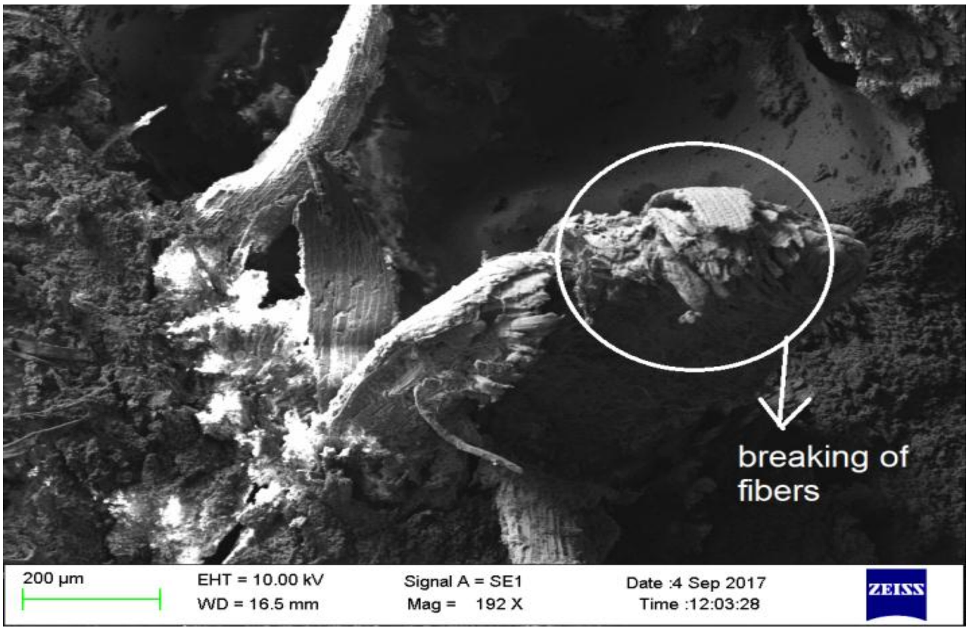


Figure 10. Micrograph of LCBL after Subzero treatment

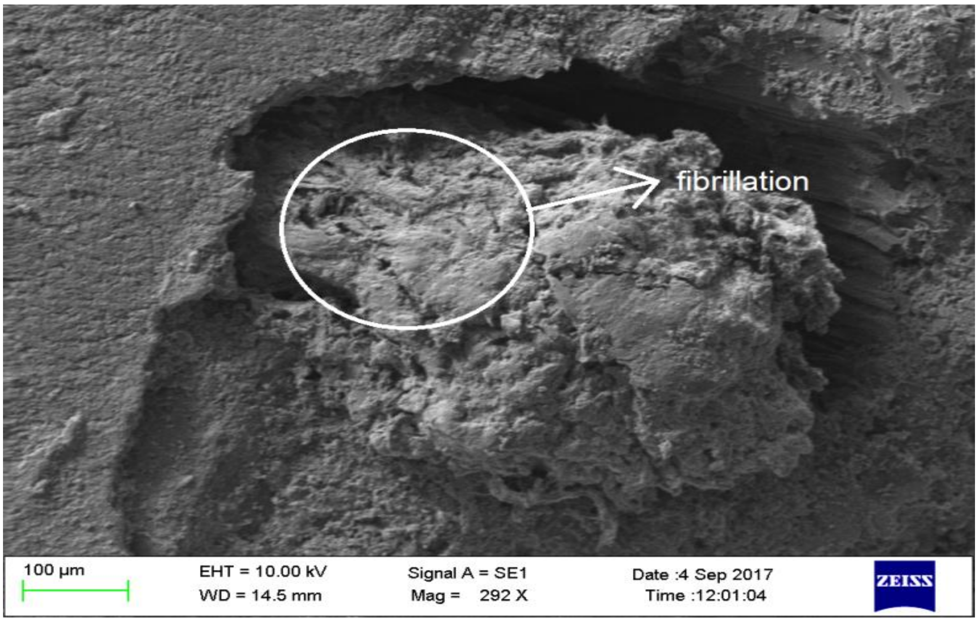


Figure 11. Micrograph of LBL after Saline treatment

The change in fiber morphology can be well observed in the above micrographs. The fractured surface reveals the main cause of failure is due to fiber debonding as well as breaking of fibers and fibrillation of fibers [9]. No crack growth has been observed in matrix of any of the composite samples.

IV. CONCLUSIONS

The following conclusions are drawn from the study.

1. Different types of chemically treated natural fiber reinforced hybrid composites were fabricated using hand lay-off technique.
2. The weight change and percentage of moisture absorption of various composite samples have been studied under different environmental conditions viz. steam, saline and subzero.
3. The percentage of moisture absorption varies with time till the saturation point attended.
4. From the fractured surface SEM studies, it is clear that fiber breaking is the predominant mode of failure which may be due to the strong inter lamellar bonding of fibers after chemical modification.

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