

Study on Distilled/Sea Water Absorption Behaviour Influenced by Non-Uniform Long Piled up Coir Fiber Composites

Moorthy M Nair¹, Shambhavi Kamath M², Dr Nagaraj Shetty³

P.G. Student, Department of Civil Engineering, Manipal Institute of Technology, Manipal, Karnataka, India¹

Assistant Professor, Department of Civil Engineering, Manipal Institute of Technology, Manipal, Karnataka, India²

Assistant Professor, Department of Mechanical Engineering, Manipal Institute of Technology, Manipal, Karnataka, India³

ABSTRACT: Long coir fibers tend to have higher strength than short coir fibers. Taking this into consideration non uniform long coir fibers reinforced epoxy composites impregnated with sawdust filler was fabricated using hand-layup technique as a result of polymer reduction. Moisture absorption test was conducted as per ASTM D 570 standard. Piled up coir fibers offer varying resistance against penetration of epoxy polymer matrix through the fibers resulting in Non-uniform bonding throughout the composite laminate. Water absorption pattern of composites exhibited Fickian behaviour at room temperature (27°C). Moisture absorption test in sea water and distilled water at room temperature showed higher value of moisture absorption percentage and diffusion coefficient due to weak bonding between fiber and matrix causing fiber to absorb more amount of water. Composite specimens were photographed to analyse the macroscopic defects during fabrication, machining and water immersion.

KEYWORDS: Composite, Diffusion coefficient, Epoxy, Macroscopic defects, Piled coir fibers, Sawdust, Tensile strength.

I. INTRODUCTION

Plant based natural fibers like coir, jute, banana, cotton, sisal, kneaf etc have gained attention due to increased environmental awareness and global concern. Unique properties of these fibers such as low cost, ease of availability, CO₂ neutrality, low density, biodegradability have added advantage in fabrication and application. The two major drawbacks of natural fibers are weak adhesion with the matrix material as a result of incompatibility, reduction in mechanical performance was noticed and high water absorption rate due to its hydrophilic nature. Z. sarani [1] investigated that hydrophilic nature of fibers led to weak bonding between fiber and matrix, dimensional instability, matrix cracking, poor mechanical property and reduces the durability of the composite. Initial treatments are performed before the fabrication to roughen the fiber surface so as to improve on adhesion and reduce the moisture intake percentage.

Moisture diffusion in polymeric composite is governed by three mechanisms. The first involves diffusion of water molecules through the micro gaps between polymer chains. The second involves capillary transport through the gaps and flaws at the interfaces between fiber and the matrix. This is a result of poor wetting and impregnation during the initial manufacturing stage. The third involves transport of micro cracks in the matrix arising from the swelling of fibers (particularly in the case of natural fiber composites). Espert A et.al [2].

In this study, effect of piled up long coir fiber in sea and distilled water is investigated. The key factor in plant based natural fiber affecting capability of moisture absorption is fiber content. Yihui Pan and Zheng Zhong [3]. In this case sawdust being hydrophilic in nature adds up to water absorption percentage. Water propagating through gaps and flaws on interface between fibers and matrices result in interface debonding concluding mechanical degradation. Espert et.al

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[2]. A study is carried out on moisture intake percentage and percentage soluble matter lost to justify mechanical degradation.

II. MATERIALS AND PROCESSING

A. Alkaline treatment of coir fiber

Piled up coir fibers were treated with 6% NaOH solution for 72 Hours. Coir fibers were then cleaned several times with distilled water till no colour change and turbidity in water was observed. Cleaned fibers are oven dried at 65°C till a constant weight is reached.

B. Processing of composite

Natural coir fibers of length 100 to 150mm (Density = 1.2 gm/cm³) were selected as reinforcement material in this investigation. Composite laminates were fabricated by weight proportion as shown in TABLE 1. The matrix material of epoxy resin (LY556) and the filler material of sawdust (density = 0.8 gm/cm³, Sp. Gravity = 2.68, Porosity = 0.37, Particle size < 75µm) were used. Hand layup technique was used for fabricating particulate filled Coir epoxy composites. Petroleum wax (releasing agent) was applied to the mould surface before the fabrication. Epoxy and hardener (HY951) by ratio (10:1) by weight is mixed along with sawdust filler for 10 minutes. This mixture is laid in to the mould of volume 300mm*300mm*3.2mm. Long coir fibers are distributed throughout the mould volume. Remaining epoxy sawdust mixture is distributed above the coir fibers uniformly. Composites are allowed to cure at room temperature for 24 hours with 10kgs load above the mould.

A change in density will be observed in actual composite laminate when compared to theoretical density due to the presence of void content which accounts in water absorption. Air void content is calculated using Formulae (1).

$$\text{Air void content (\%)} = \frac{\text{Theoretical density} - \text{Actual density}}{\text{Theoretical density}} \dots\dots\dots (1)$$

TABLE 1 Percentage proportions of coir, epoxy and sawdust by weight

Sample No	Coir fiber proportion by weight (%)	Epoxy resin proportion by weight (%)	Sawdust proportion by weight (%)
1	15	85	0
2	15	80	5
3	15	75	10
4	15	70	15

Water absorption specimen of size 75mm*25mm*3.2mm was machined as per ASTM D 570 and is immersed in distilled water and sea water at room temperature (27° C). Water absorption percentage was calculated using Formulae 2. Graph of moisture intake percentage vs. √time in Hours is plotted and diffusion coefficient (m²/sec) is calculated using Formulae 3. Percentage soluble matter lost is determined using Formulae 4 which justifies the drop in the strength due to degradation after ageing.

$$\text{Water absorption percentage (\%)} = \frac{\text{Final weight of specimen} - \text{Initial weight before immersion}}{\text{Initial weight before immersion}} \dots\dots\dots (2)$$

$$\text{Diffusion coefficient (m}^2\text{/sec)} = \pi * \left(\frac{B}{4Ms}\right)^2 * (\text{slope})^2 \dots\dots\dots (3)$$

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Where,

B = thickness of specimen (m), Ms = saturation moisture intake (%), Slope is obtained from the graph

$$\text{Soluble matter lost (\%)} = \frac{\text{Initial weight of specimen} - \text{Reconditioned weight after immersion}}{\text{Initial weight of specimen}} \dots\dots\dots (4)$$

Where,

Reconditioned weight (mg) = weight of the specimen removed from water, reconditioned at 45°C till a constant weight

III. EXPERIMENTAL RESULTS

A. Density test

Density test was carried out to determine the actual density of composite laminate. Percentage of void content was calculated using Formulae (1) as void content in the laminates accelerate water absorption rate. Increased void content was observed due to incorporation of hand laying procedure. Generally tendency of agglomeration is more in long a fibre. K L Pickering et.al [4] which is one among the reason for void content. Agglomeration of sawdust at higher filler percentage increased micro pores because of the porous nature resulting in improper curing. Higher void content of 42% was observed in 3rd sample.

Table 2 percentage void content in each sample

Sample no	1	2	3	4
Void content (%)	24.6061093	34.5869529	42.926063	37.4651433

B. Water absorption behaviour

Water absorption specimens of different proportions was machined as per ASTM standard and were immersed in distilled water (pH = 7) and sea water (pH = 8.1). Fig 1 and Fig 2 shows that weight gain of the composite increases with immersion time at initial stage and later keeps stable indicating specimens are apparently saturated with moisture. As the filler increased water absorption increases, increase in filler results in agglomeration which affects the curing of resin matrix. Water absorption percentage of samples increased with increase in sawdust filler up to 10%, as water propagating through cracks and air voids of sample is absorbed by sawdust and coir fiber due to hydrophilic nature. Coir fibre and sawdust contains cellulose and hemicellulose compositions. These compositions contain miscellaneous hydroxyl groups and carboxyl groups which would interact with water molecules via hydrogen bonding. The numerous hydroxyl groups in the cellulose and hemicellulose lead to poor interface and poor resistance of the fibres to the moisture absorption which promote the water gain. Further the porosity of sawdust (0.37) is the void space in the particle. Baker et.al [5], occupied by water/moisture enhancing water absorption percentage. Further increase in filler to 15% a decrease in water absorption percentage than 10% filler sample was noticed, as percentage void content is less in 4th sample compared to 3rd sample which inhibited moisture absorption rate of the specimen. The fabrication and machining defects observed in 4th sample was fewer compared to 3rd sample due to improved bonding between fiber and matrix.

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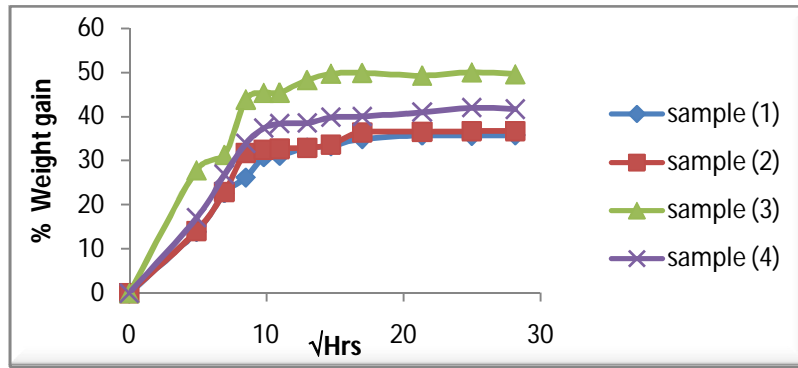


Fig 1 Percentage of distilled water absorbed

Generally coir fibers exhibit resistance against salt water. At the initial stage of immersion, ions present in the sea water accelerate the water uptake through the cracks and voids. Since distilled water is deionised, there are no ions supporting the acceleration of water uptake. Hence Diffusion coefficient of sample immersed in sea water is slightly higher than that of distilled water as represented in Table 3. Water absorption percentage of specimen in sea water is less than that of distilled water due to presence of salt in the seawater which reduces the activity of the water molecules because the salt particles presented in the seawater are less readily absorbed than water. This result in accumulation of salt particles on the surface of the specimen which could further inhibit the water absorption. So, the concentration of salt particles in the seawater inside the specimen is less than that in the seawater. This would create an osmotic pressure that acts against the water absorption. Libo Yan and Nawawi Chow [6].

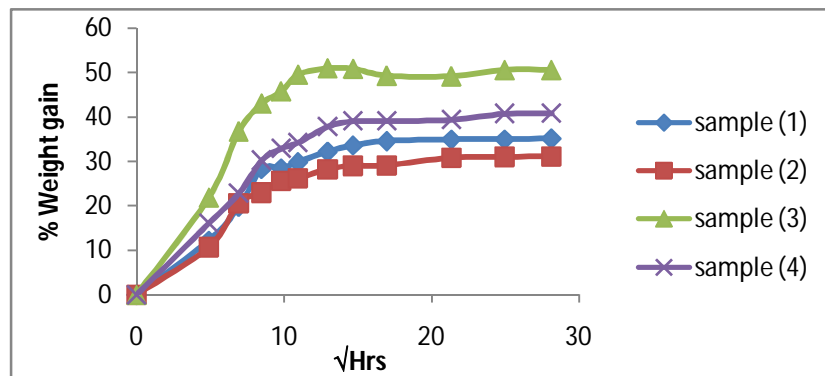


Fig 2 Percentage of sea water absorbed

TABLE 3 Diffusion coefficients of samples immersed in water (Distilled & Sea)

Sample No	Diffusion coeff – Distilled water (m ² /sec)	Diffusion coeff – Sea water (m ² /sec)
1	1.3037E-12	1.30381E-12
2	1.3117E-12	1.2788E-12
3	1.6025E-12	1.73321E-12
4	1.4707E-12	1.67488E-12

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Resulted water absorption assist in loss of soluble matter (lignin, pectin, hemicellulose, cellulose) from the composite laminate. Loss of soluble matter justifies the significant drop in mechanical performance after ageing. Increased absorption percentage has resulted in increased loss of soluble matter as in Table 4. The overall loss in soluble matter is higher in case of third sample i.e., 2.2689% in distilled water and 1.494 % in salt water due to higher water absorption percentage. Soluble matter lost in salt water ageing is less compared to distilled water, as ions present in the sea water clogged the cracks and voids inhibiting the rate of absorption and loss of soluble matter.

TABLE 4 Percentage soluble matter lost after immersion in salt and distilled water

Type of immersion	Sample 1	Sample 2	Sample 3	Sample 4
Distilled water	1.61342676	1.89285722	2.26899189	2.20473839
Salt water	0.61659347	0.76186524	1.49430331	1.28476599

IV. MACROSCOPIC SPECIMEN MORPHOLOGY

Specimen surface were photographed to study and analyse the macroscopic defects. Generally microscopic analysis is carried out when there is no noticeable macroscopic defects present on the specimens. In this study more of macroscopic defects on specimen could be distinguished through naked eyes.

Piled up coir fibers are very difficult to separate from each other as it is tiring and time consuming. Piled up coir fibers used for fabrication of composite laminate offered resistance against penetration of epoxy resin matrix through the coir fiber surfaces which resulted in weak fiber-matrix interface.



(a)

(b)



(c)



Fig 3 (a), (b), (c), (d), (e) Macroscopic defects observed in specimen

Fig 3(b) shows the partly bonded coir fiber with matrix material, where in remaining part of coir surface does not hold a trace of epoxy matrix in it. Due to weak bonding between fiber and matrix, fibers were subjected directly to external environment as in Fig 3(a) which resulted in higher water intake percentage. Higher water intake percentage has led to thickness swelling which developed cracks on specimen surface as in Fig 3(c). Weak bonding between fiber-matrix has developed machining difficulties causing matrix material to chip off from the fiber surfaces as in Fig 3(e), subjecting fiber to externalities. Air voids is one of the common defects that most of the materials experience due to unskilled and out-dated methodologies. It is more often in composites to have voids, cracks and flaws made by hand lay-up process. Libo Yan and Nawawi Chow [6]. Similarly air voids was observed in specimen surface Fig 3(d) which is a major defect that affects the mechanical performance and water absorption intake percentage. All the mentioned macro defects make composite laminate squander.

V. CONCLUSION

In this study an investigation was carried out on an influence of piled up coir fibers on tensile performance and water absorption property of coir fiber/epoxy composite with sawdust as filler. Maximum water absorption percentage noticed was 51.2% (Distilled water) & 50.5% (Salt water) with filler composition of 10%. As the water absorption increases Diffusion coefficient and percentage soluble matter lost also increases. A maximum Diffusion coefficient of $1.6025E-12$ (Distilled), $1.73321E-12$ (salt water) was observed for 3rd sample. Diffusion coefficient of sample in salt water is higher than distilled water due to the presence of ions which diffuse through at the initial hours of immersion, thereby clogging the cracks and reducing the water absorption percentage. 10% filler composition shows higher loss of soluble matter of 2.269% (Distilled) and 1.49% (Salt water). This loss in soluble matter justifies significant drop in mechanical performance, as soluble matter lost corresponds to lignin, cellulose, hemicellulose and pectin which adds up to the mechanical performance. The major rationale for higher water absorption & diffusion coefficient were due to (a) corrupt matrix-fiber bonding, as piled up coir fibers offered resistance against penetration of epoxy matrix resin through the fibers, (b) hydrophilic nature of coir fiber and sawdust, (c) porosity of sawdust, (d) air void percentage of composite laminates.

From this study, it is lucid that piled up coir fibers are not recommended in fabrication of coir fiber reinforced polymer matrix composites.

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