Effect of Chemical Treatment on the Mechanical Properties of Palm Fiber Reinforced Polymer composites

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Abstract - The role of natural fiber reinforced composite materials is increasing in an accelerated rate in our daily life due to its favorable properties. In the present unendurable environmental conditions natural fibers are representing superior material in terms of biodegradability, low cost, high strength and corrosion resistance when compared to conventional and man-made materials. The main objective of this experimental study is to fabricate the oil palm fiber reinforced composite and to evaluate mechanical properties such as tensile strength, flexural strength and impact strength. There are three different type of laminates are fabricated by hand lay-up method by using oil palm fiber as reinforcing material with epoxy resin as matrix. The specimen is prepared according to ASTM standard s and the experiment has been carried out by using universal testing machine (UTM). From the experimental results, it has been observed that the specimen is treated for 3hours by NaOH exhibited superior properties except impact strength. Impact strength is greater for the specimen which is non treated. Morphological examinations are carried out by scanning electron microscope (SEM) analysis.

Keywords - Mechanical properties, Scanning electron microscope (SEM), Oil palm fiber composites, PFIBW, PFIB3H, PFIB15H

1 Introduction

Now-a-days, natural fibers reinforced composites exhibit superior mechanical properties than synthetic fiber reinforced polymer composites due to its favorable properties. This is due to their unique and attractive properties compared to other materials; that is, they own excellent impact and abrasion resistance, high strength-to weight ratio, high durability and high corrosion resistance which fulfill the requirement for many designs in manufacturing components [1, 2]. Growing environmental awareness throughout the world has triggered a paradigm shift towards designing materials compatible with the environment. The use of reinforcing fibers in both thermoplastic and thermo set matrix composites provide positive environmental benefits with respect to ultimate disposability and raw material utilization [3,4]. The main bottle necks in the broad use of these natural fibers in various polymer matrixes are poor compatibility between the fibers and the matrix, and the inherent high moisture absorption, which brings the less usage of natural fibers[5,6]. The efficiency of a fiber reinforced composite depends on the fiber/matrix interface and the ability to transfer stress from the matrix to the fiber. This stress transfer efficiency plays a dominant role in determining the mechanical properties of the composite [7].

New material and technological solutions are widely proposed and investigated to meet sustainability requirements and natural fibers represent one of the most studied materials. The work presented here investigated the mechanical behaviour of a sustainable composite system made by pozzolanic mortar reinforced with hemp fiber grids[8].Green composites which concern towards environmental issues and, on the other hand, the need for more versatile polymer-based materials has led to increasing interest about polymer composites filled with natural organic fillers[9]. The enhanced thermal conductivity of polymer composites study aims at investigating package materials based on polymer matrix for microelectronics. The next generation package materials are expected to possess high heat dissipation capability in addition to low coefficient of thermal expansion (CTE) as the accumulated heat from high performance electronic devices should be removed for proper operation[10]. The flexural properties of AgentaPinnatafiber reinforced Epoxy composites is determined in the investigation of mechanical properties of Indian bowstring hemp fiber as a natural fiber and polyester resin as a matrix, Method used is Hand layup method for fabrication[11]. The degree of fiber–matrix adhesion and its effect on the mechanical reinforcement of short henequen fibers and a polyethylene matrix was studied. The surface treatments were: an alkali treatment, a silane coupling agent was used[12].Natural fibers are emerging as low cost, lightweight and apparently environmentally superior alternatives to glass fibers in composites[13]

2 Materials and Experimentation

High density general purpose polyester resin Fiber bond 333 was supplied by Ruia Chemicals private limited. The viscosity of the polyester resin is 700-250 CPs at 25^0 C and the specific gravity is 1.10 to 1.13 at 25^0 C. The catalyst and accelerator used was methyl ethyl ketone peroxide and Cobalt Naphthalene.Oil palm fiber is produced from oil palm's vascular bundles in the empty fruit bunch. The fibers were collected from the oil palm Kollem. The following are the specifications of oil palm fiber.

Table 1 Properties of Oil Palm Fiber

Properties	value
Moisture content	12-15%
Oil content	<2%
Length	5-15cm
Impurities	<3%
Mean diameter	.7mm

2.1 Fiber chemical treatment

The fibers were washed with 2% detergent solution to remove contaminants, dirt and dust. The extracted fibers were air dried for 24 hours in 60^0 C. For the selection of suitable fibers optical microscopy was used. Then the fibers were cut in to 5-7 mm. In this study the extracted fibers are treated with acetic acid for 3 h at room temperature. Then the fibers are rinsed with distilled water and dried ion 60^0 C for 24 hours. Again the fibers are treated with 0.06 M sodium hydroxide (NaOH) for 3 h, 15 h for each specimen. Then the fibers are rinsed with distilled water and dried.

Acetylation is an esterification method which should stabilize cell walls in terms of humidity absorption.The cellulose molecules of natural fibershave large numbers of hydroxyl molecules and that leads to hydrophilic properties in natural fibers. The hydrophilic properties exhibit poor bonding between the fibers and polymeric matrices. Waxy residues on the fiber surface also resulting poor bonding characteristics of these fibers[16]. Investigations on alkalization of fibres with a solution of NaOH reveals better improvement in the strength of composites as a result of optimization of chemical bonding between fiber and matrix [17]. The removal of surface debris and dimensional changes of fibers results in the enhancement in bonding [16]. An increase in Weibull modulus also showed better consistency in tensile strength of the alkali treated fibres[18]. If the time of soaking increases to 15 hours , it may lead to corrosion of raw fiber and thus it results in the reduction of mechanical properties.

In this study , three composite were prepared using hand lay-up method. We prepared several composite by using General purpose resin reinforced with oil palm fiber in accordance with the time difference in treatment. The volume fraction of fibre bundles is 72% with respect to the polyester resin[18].Three type of composite specimen that have to be prepared as follows[14].

1). Oil palm fiber without chemical treatment(PFIBW)

2). Oil palm fiber chemically treated for 3 hours.(PFIB3H)

3). Oil palm fiber chemically treated for 15 hours(PFIB15H)

Figure 1 Raw Oil Palm Fiber

Figure 2 Fabricated Oil Palm fiber Composite

2.2 Experimental procedure

Mechanical properties of the developed composites were studied considering the tensile, flexural and impact characteristics.Both tensile and flexural test were performed according to ASTM standards D638 and D790 in Instron universal testing machine model 1125 equipped with a 500 kg load cell. The cross head speed of tensile specimen was 5 mm/minute. For the flexural test a specimen with 50x25x4 mm^3dimension is used. For the impact test a specimen of 70x10x4 mm^3 dimension used in a computerised Chary test machine. The failure of surface was investigated by scanning electron microscopy. Scanning electron microscopy is used to investigate the effect of different surface treatments and their effect on properties of composite. The analysis was done by using Jeolneoscope JCM-6000. Fracture surface of the samples was coated with platinum and analysed using SEM operated at 15 kV.

3 Results and discussion

Tensile, flexural and impact behaviour was obtained and presented in figures including samples of SEM micrographs. It should be noticed that the orientation of fibbers are not taken in to account, ie. Fibbers are oriented randomly.

3.1 Tensile behaviour

Figure 3 shows the tensile behaviour of developed specimens. From the figure it is clear that all the specimens were exhibit brittle behaviour. In the current study it can be seen that the tensile strength of PFIB3H is more than that of PFIB15H and also the tensile strength of PFIBW was greater than that of PFIB15H.The summery of tests of each composite is listed in Table1. In this table, it can be seen that the chemical treatment of fibber enhances the mechanical properties of oil palm fiber,since there is a significant increase in tensile strength from 21.5 MPa to 26.6 MPa. But the continuous chemical treatment over 15 hours the tensile strength is decreased to 19.92 MPa which is less than non treated fiber.

The SEM observation of Figure 4 indicates that there is less fiber pull out since a good adhesion of fibers with matrix occurs. This shows the support of the natural fibers to the matrix during the loading conditions [7].Here the chemical treatment of fiber with NaOH helps to gain good interfacial adhesion [1,15]. The high strength of thermoset compared to the thermoplastics offers high interfacial adhesion to the natural fibers. This is the main reason for the chemical treatments to the natural fibers when they are reinforced with thermosets [1,15].

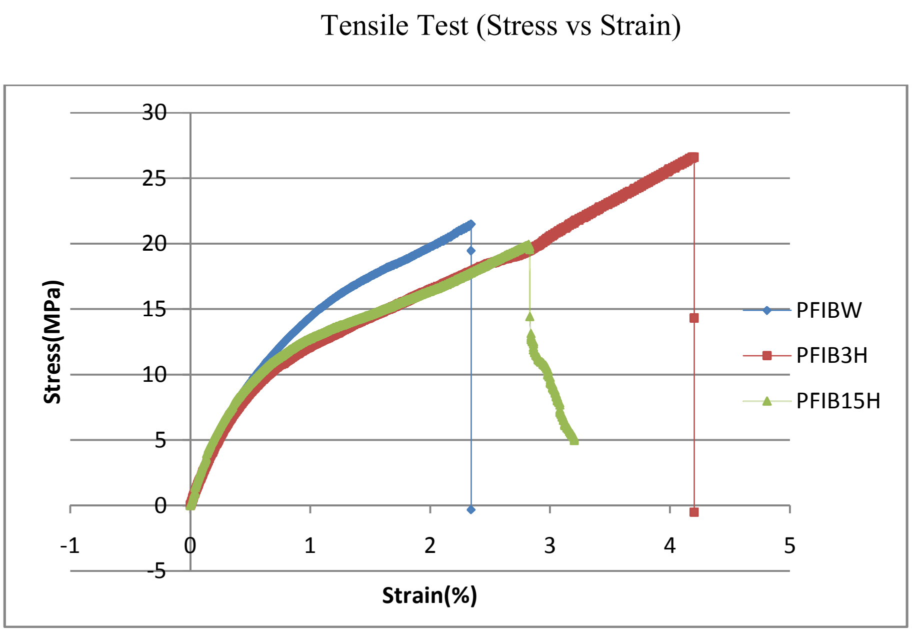

Figure 3 Tensile stress-strain diagram

Table 2 Ultimate Tensile Strength and Young's Modulus

Types of composites	Ultimate tensile strength(MPa)	Young's Modulus(MPa)
PFIBW	21.5	2280
PFIB3H	26.6	2190
PFIB15H	19.92	2490

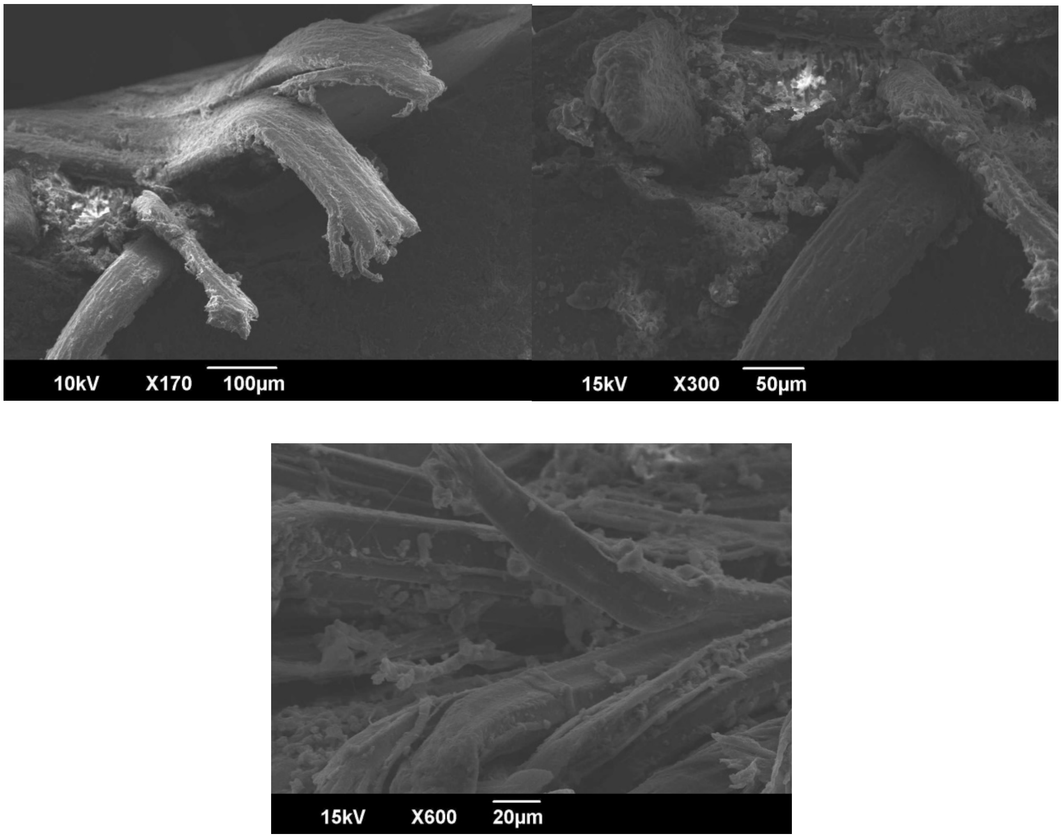

Figure 4 SEM Micrographs of Oil Palm Fiber Composite

3.2 Flexural Behaviour

The flexure properties of the composite samples are tested and the experimental values are presented in the Table 2. The flexural strength comparison of different hybrid composites is presented in Fig. 5. From figure it is asserted that the flexural load carrying capacity of PFIB15H is better than that of PFIBW and the flexural load carrying capacity of PFIB3H is less than that PFIBW. From the table it can be seen that the chemical treatment enhances the flexural property up to a limited period of processing time after that the flexural property decreasing.

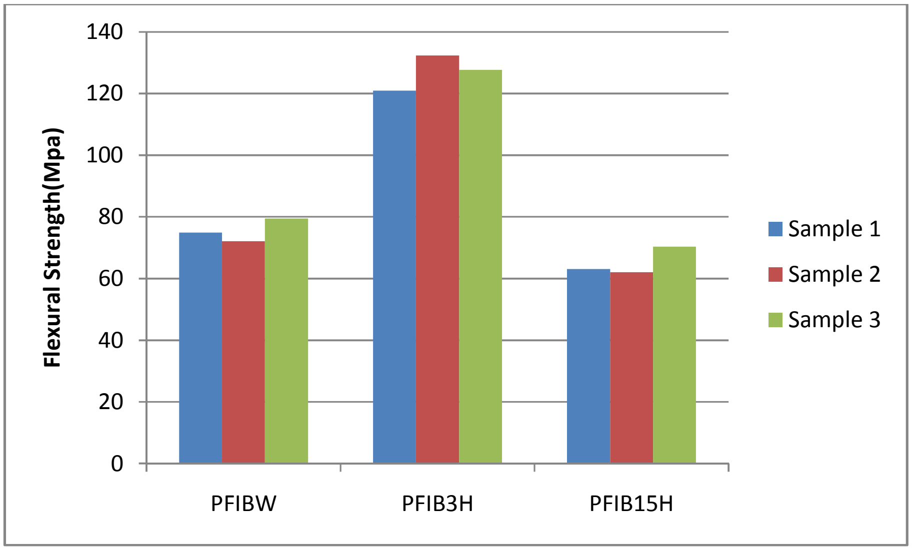

Figure 5 Flexural Strength Comparisons of Different Specimens

Table 3 Average Flexural Strength of Different Specimen

Type of specimen	Flexural Strength(MPa)
PFIBW	75.5
PFIB3H	127.033
PFIB15H	65.167

3.3 Impact Strength

The impact test is carried out for evaluating the impact load carrying capacity of the different composite specimens and the charpy test is used for the investigation. The loss of energy is found out from the impact testing machine.

The impact strength comparison of different composite samples is presented in the Fig. 6. The average impact energy of three samples is tabulated in the Table 3. From the figure it is asserted that the maximum impact strength is for PFIBW which is non-treated and hold 0.233 J. And also the impact strength of PFIB15H is greater than that of PFIB3H.

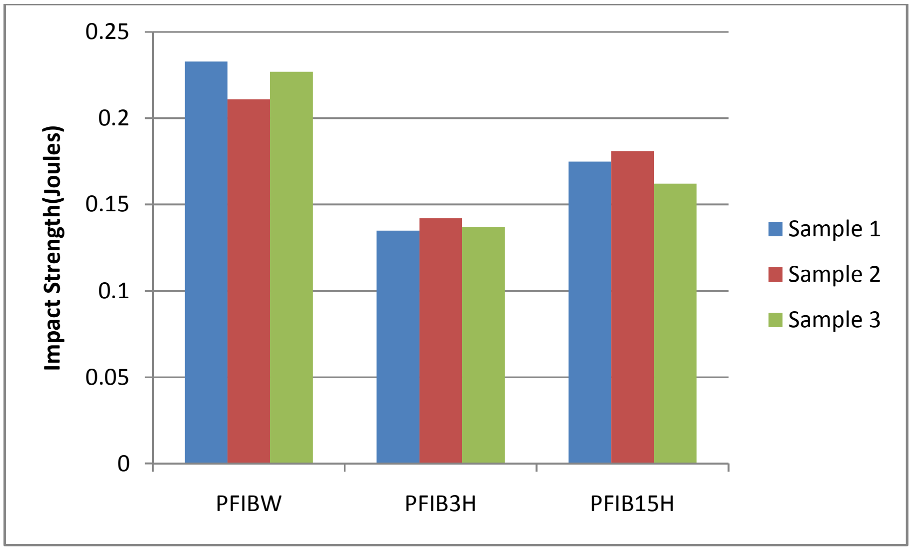

Figure 6 Impact Strength Comparisons of Different Specimens

Table 4 Average Impact Strength of Different Specimen

Type of specimen	Impact Strength(Joules)
PFIBW	0.224
PFIB3H	0.138
PFIB15H	0.173

4 Conclusions

The composites are fabricated from the fibers which are chemically non treated, chemically treated for 3 hours and chemically treated for 15 hours. The mechanical properties such as tensile strength, flexural strength and impact strength of these composites are evaluated. Investigations on alkalization of fibres with a solution of NaOH reveals better improvement in the strength of composites as a result of optimization of chemical bonding between fiber and matrix. If the time of soaking increases to 15 hours leads to drop in mechanical properties. The following conclusion has been derived from the experimental investigation.

- The composite which is chemically treated for 3 hours have more tensile strength than the chemically treated 15 hours and non-treated composites.
- The maximum flexural strength is holding by the chemically treated 15 hours composite followed by non-treated composite.

- The highest impact strength is holding by non-treated composite followed by chemically treated 15 hours composite.
- It can be seen that there is less fiber pull out, since a good adhesion of fibers with matrix occurs.
- It is suggested that the composite which is chemically treated for 3 hours is used as a alternate for synthetic fiber composite based on tensile and flexural considerations and use non treated fiber based on impact strength considerations.

References

[1] Agarwal, P. (2007). Higher education in India: Growth, concerns and change agenda. *Higher Education Quarterly*, Vol.61 (2), 197-207.

[1] Yousif, B. F. (2010). Effect of Oil Palm Fibers Volume Fraction on Mechanical Properties of Polyester Composites, *International Journal of Modern Physics B*, Vol.**24** (23), 4459–4470.

[2] Shalwan, A. and Yousif, B. F. (2013). In State of Art: Mechanical and Tribological Behaviour of Polymeric Composites Based on Naturalfibers, *Materials &Design*, Vol.48, 14–24.

[3] Glew, D. Stringer, L.C. Acquaye, A.A and Mcqueen-Mason, S, (2012). How Do End of Life Scenarios Influence the Environmental Impact of Product Supply Chains? Comparing Biomaterial and Petrochemical Products, *Journal of Cleaner Production*, Vol.30, 122–131.

[4] Kumar, S. Panda, A. K. and Singh, R. K. (2011). A Review on Tertiary Recycling of High-Density Polyethylene to Fuel, Resources, *Conservation and Recycling*,Vol.55, 893–910.

[5] Chai, M. W. Bickerton, S. Bhattacharyya, D. and Das, R. (2012). Influence of Natural Fiber Reinforcements on the Flammability of Bio-Derived Composite Materials, *Composites B*, Vol. 43(7), 2867–2874.

[6] Hejazi, S.M. Sheikhzadeh, M. Abtahi, S.M. and Zadhoush, A. (2012). A Simple Review of Soil Reinforcement by Using Natural and Synthetic Fibers, *Construction and Building Materials*, Vol. 30, 100–116.

[7] Azwa, Z.N Yousif, B.F..Manalo, A.C and Karunasena, W. (2013). A Review on the Degradability of Polymeric Composites Based on Naturalfibers, *Materials&Design*,Vol.47, 424–442.

[8] DomenicoAsprone , Massimo Durante , Andrea Prota and Gaetano Manfredi, (2011). Potential of Structural Pozzolanic Matrix–Hemp Fiber Grid Composites, *Consruction and Building Materials*, Vol.25, 2867-2874.

[9] La Mantiaand, F.P. Morreale, M. (2011). Green Composites: A Brief Review,Composites: Part A,Vol.42, 579–588.

[10] Geon-WoongLeea, Min Park, Junkyung Kim, Jae Ik Lee and HoGyu Yoon, (2006). Enhanced Thermal Conductivity of Polymer CompositesFilled with Hybrid Filler, *Composites: Part A*, Vol.37, 727–734,

[11] H.Y.Sastra ,Flexural Properties of Agenta Fiber Reinforced Composites, American Journal of Applied Sciences,p. 21-24,(2005)

[12] Herrera-Franco, P.J. Valadez-Gonza´Lez, A. (2005). A Study of The Mechanical Properties of Short Natural-Fiber Reinforced Composites, *Composites: Part B*, Vol.36, 597–608.

[13] Joshi, S.V. Drzal, L.T. Mohanty, A.K. Arora, S. (2004). Are Natural Fiber Composites Environmentally Superior to Glass Fiber Reinforced Composites?, *Composites: Part A* Vol. 35, 371–376.

[14] Aldousiri, B. Alajmi, M. and Shalwan, A. (2013). Mechanical Properites of Palm Fiber E inforced Recycled HDPE, *Advances In Material Science And Engineering*, Article D, 3-5.

[15] A. I. S. Br ´ Igida, V. M. A. Calado, L. R. B. Gonc¸Alves, and M. A. Z. Coelho, (2010) Effect of Chemical Treatments on Properties of Green Coconut Fiber, *Carbohydrate polymers*,Vol.79(4), 832–838.

[16]Mwaikambo, L. (2002). Plant Based Resources For Sustainable Composites. *University of Bath.*

[17] Bisanda E T N. (2000). The Effect of Alkali Treatment on the Adhesion Characteristics of Sisal Fibers. *Appl Comp Mat*, Vol.7, 331-9.

[18]Towo, A. N. Ansell, M. P. Paster, M. L. and Packham, D. E. (2005). Weibull Analysis of Microbond Shear Strength at Sisal Fibre- Polyester Resin Interfaces. C*omp Int,* Vol.12, 77-93.