

Flexural Strength Analysis of Modified Coir Fiber Composites

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ABSTRACT: Coir fiber is a suitable raw material to serve the purpose of green composite. Both physical and chemical treatments were performed to minimize the hydrophilic nature of coir fiber. Alkali treatment with NaOH (20%, chemical in nature) were performed on coir fiber by varying the treatment time duration for 1hr, 3hr, 5hr and 7hr. Oven treatment (physical in nature) were performed for 5hr at a temperature of 90⁰C on NaOH treated coir fiber. From the FESEM, XRD and FTIR analysis it has been confirmed that 20% NaOH treated coir fiber for 3hr treatment is better for composite preparation due to proper roughness and surface characteristic. FTIR study confirms the reduction of hydrophilic group and XRD study confirms the crystallinity. Lapox as a resin with K-6 hardener used for composite preparation along with 15% (wt/v) coir fiber. Instron analysis confirms that flexural strength is highest for composite prepared with 3hr NaOH treated coir fiber.

KEYWORDS: Coir fiber, NaOH treatment, Oven treatment, FESEM, XRD, FTIR, INSTRON, Flexural strength

I. INTRODUCTION

Composite has significant importance in modern days. Any composite consist of one or more discrete phases embedded in a continuous phases to produce a multiphase material which possesses the properties which is not obtainable with the individual constituent material acting alone. Discrete and matrix phase are two basic phases of any composite. Matrix phases hold the spread phases whereas discrete phases provide the strength, rigidity and hardness to composite. Generally fiber is used as discrete material and epoxy as matrix materials for natural composites. Fiber is a rope or string utilized as a part of composite materials. It comprises of a large number of filaments having a measurement between 5-15 micrometres. There are numerous advantages of natural fiber on reinforcing material due to properties like low density, minimal effort, good thermal coefficient, strength and biodegradability [1,7]. All these properties make natural fiber mainstream over synthetic fiber. The cellulose and lignin content of natural fiber plays major role in composite preparation. From the literature survey it has been found that coir fiber is suitable for the flexural strength analysis due to its superior properties over other composite and ongoing research interest. The objective was to prepare a composite of high flexural strength and contribute the quality scientific information. Several parameters and useful information has been taken from the literature survey for the improvement of flexural strength [15-24].

Starting from the basic definition to current research work in the field of natural fibers with basic element has been discussed by Chandramohan et al., 2011 [1]. Coir fiber reinforcement has been discussed briefly in Verma et al. paper 2013 [2]. Mechanical properties of coir fiber composite has been studied by many people. Several kind of chemical treatment like NaOH, KMnO₄ and H₂O₂ with different time duration has been performed for the improvement of mechanical properties. Chemical treatment with 20% NaOH for 3hr and physical treatment at a temperature of 90⁰C using an oven for 5hr are suitable and preferred [3]. The untreated coir fiber washed with an incubator under mechanical stirring provided with certain temperature range [4]. Calculation of the flexural strength using universal testing machine with different ASTM standard has been discussed in Manikam et al. paper [5]. Mechanical testing like stress-strain curve and different failure of chemically treated coir fiber has been discussed in Mir et al. and Natarajan et

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al. [6,10]. Fabrication of composite with fiber weight percentage, fiber length and specimen preparation for flexural strength measurement of composites has been discussed briefly in thesis work [7].

II. MATERIAL AND METHOD

Coir fiber is extracted from the husk of coconut. Physical and chemical treatments are necessary to make it suitable for matrix reinforcement. It is also useful for enhancement of surface morphology i.e. surface roughness and moieties. Reducing the hydrophilic group, moisture contains and crystallinity improvement are also part of the treatments. The changes occurred in the fiber during the treatments studied with the help of FESEM, XRD and FTIR. FESEM provide the surface morphology data, XRD about the characteristic properties and FTIR about the chemical bonding.

Matrix materials, fiber and hardener are necessary for composite fabrication. Polymer matrix material are most widely used among all due to its cost effectiveness, ease of fabrication with less tooling rate and tremendous room temperature property. The common matrix material are epoxy, polyurethane, phenolic, polyester, polyetheretherketone (PEEK), vinyl ester etc. Among these material PEEK and epoxy are generally utilized however epoxy is favored because of its better properties like adhesiveness to wide variety of fibres, prevalent mechanical and electrical properties and great execution at elevated temperatures. Epoxy is picked as the matrix material for the composite preparation. Chemically it has a place with the "epoxide" family and its regular name of epoxy is bisphenol A diglycidyl ethers. Lapox is used as a resin along with K-6 hardener. Coir is used as fiber materials.

II-A. PREPARATION OF COIR FIBER

Coir is a versatile lingo-cellulosic natural fibre extracted from mesocarp tissue, or husk of the coconut. Raw coir were extracted and broken into small pieces for drying in sun rays. Dust of coir was separated by traditional method. The process was repeated several times to prepare the coir fiber.

II-B. CLEANING OF COIR FIBER

Coir fiber washed with 2% detergent solution to remove the surface dirt using an incubator with a rotation of 20 RPM, temperature of 30^o-60^oC, duration of 2hr for uniform cleaning. Fiber removed from the incubator and washed with distilled water followed by drying with an air dryer to remove the extra moisture. Again it is dried with an oven at a temperature of 20^oC to gain constant weight. Extra surface dirt separated from single coir fiber to prepare it as untreated fiber [8].

II-C. CHEMICAL TREATMENT USING NaOH

Raw coir fiber soaked in 250ml NaOH solution (20% concentration) for a time duration of 1hr, 3hr, 5hr and 7hr. The fiber were removed from the solution and washed with distilled water to remove the excess solution present in the fiber. The extra moisture evacuated from the fiber using a dryer.

II-D. PHYSICAL TREATMENT USING OVEN

Raw fiber and NaOH treated fiber were taken inside the oven and treated for 5hr at a temperature of 90^oC. The fiber removed from the oven after the treatment and packed with different polythene packet coated with Aluminum foil. It has been kept inside desiccators to protect from the atmospheric moisture. After the physical treatment the coir fiber was ready for the scientific analysis.

II-E. COMPOSITE FABRICATION

A handmade indigenous wooden mold prepared with plywood, glue and small nails was used for fabrication of composites. The length of wooden mold was 15 cm, breadth was 5 cm and thickness was 6 mm. Releasing plastic was applied in the bottom of the wooden mold and heavy duty silicon spray was applied to releasing plastic for the easy removal of the composite plate. Initially, epoxy and hardener were mixed together in a beaker on a weight percentage of 10:1 to form matrix. Raw and treated coir fiber were cut into small pieces (20 mm in length) and mixed with a weight percentage of 15% with the epoxy. A stirrer were used for 10 minutes to maintain the uniformity of the mixture. The matrix mixture distributed uniformly over the wooden mold and strapped down with an iron roller to evade and eliminate the air bubbles. The top of wooden mold filled with composite is covered with a glass coated with releasing plastic and sprayed with silicon spray. A heavy load is applied to remove the extra matrix. The composite plate were removed from the wooden mold after the curing at room temperature for 24hr [9]. The small hacksaw and zig saw were

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used to prepare the specimen for flexural strength analysis. For flexural strength; length, breadth and thickness were 50 mm, 30 mm and 6 mm.



Figure 2.1. Composite Fabrication with different step

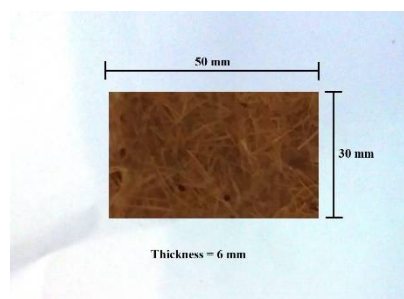
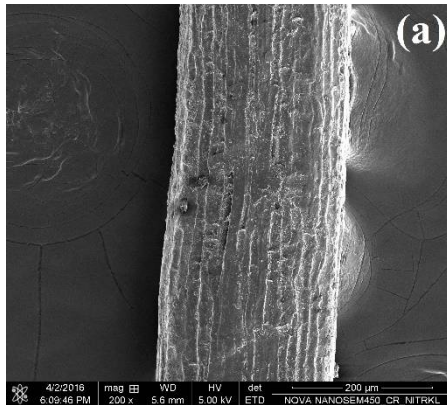


Figure 2.2. Specimen for flexural strength

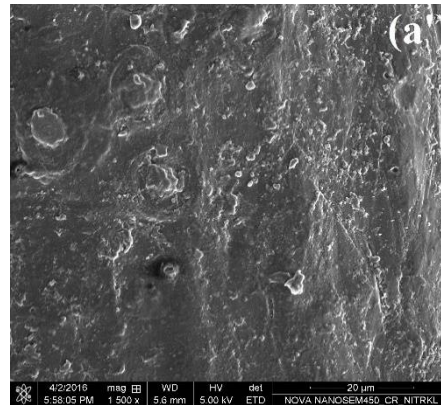
III. RESULT AND DISCUSSION

III-A. SURFACE MORPHOLOGY USING SCANNING ELECTRON MICROSCOPE

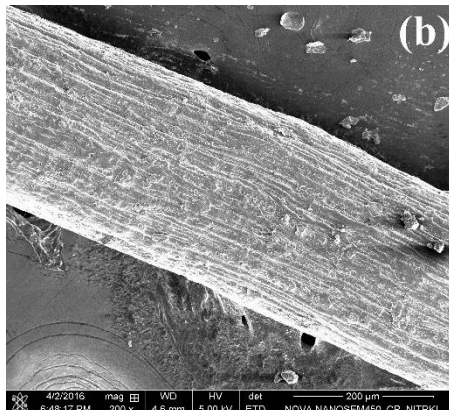
Mechanical properties of composite depend on fiber reinforcement and fiber content. In below (Figure 3.1), figure (a, a') shows the surface morphology of untreated single coir fiber with two different magnification. The fiber surface is looking smooth which indicates that the surface is still filled with impurities. The surface morphology of different treatments has been demonstrated with rest of figures. It confirm that surface roughness is increasing for (b, b') and (c, c'). Surface bond breaking begins with (d, d') and (e, e'). Impurities and surface bond breaking are unsuitable for adhesion in between fiber and matrix. Among all (c, c') is suitable for the fiber reinforcement with the matrix materials [3].



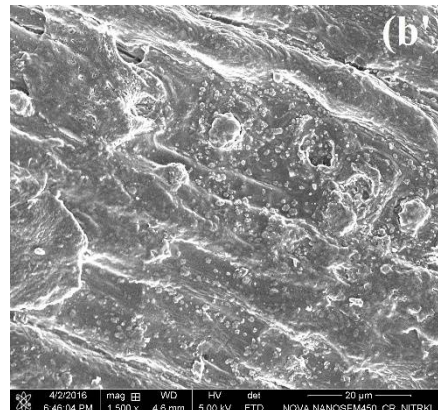
(a) Raw coir fiber at 200µm



(a') Raw coir fiber at 20µm



(b) 1hr NaOH treated coir fiber at 200µm



(b') 1hr NaOH treated coir fiber at 20µm

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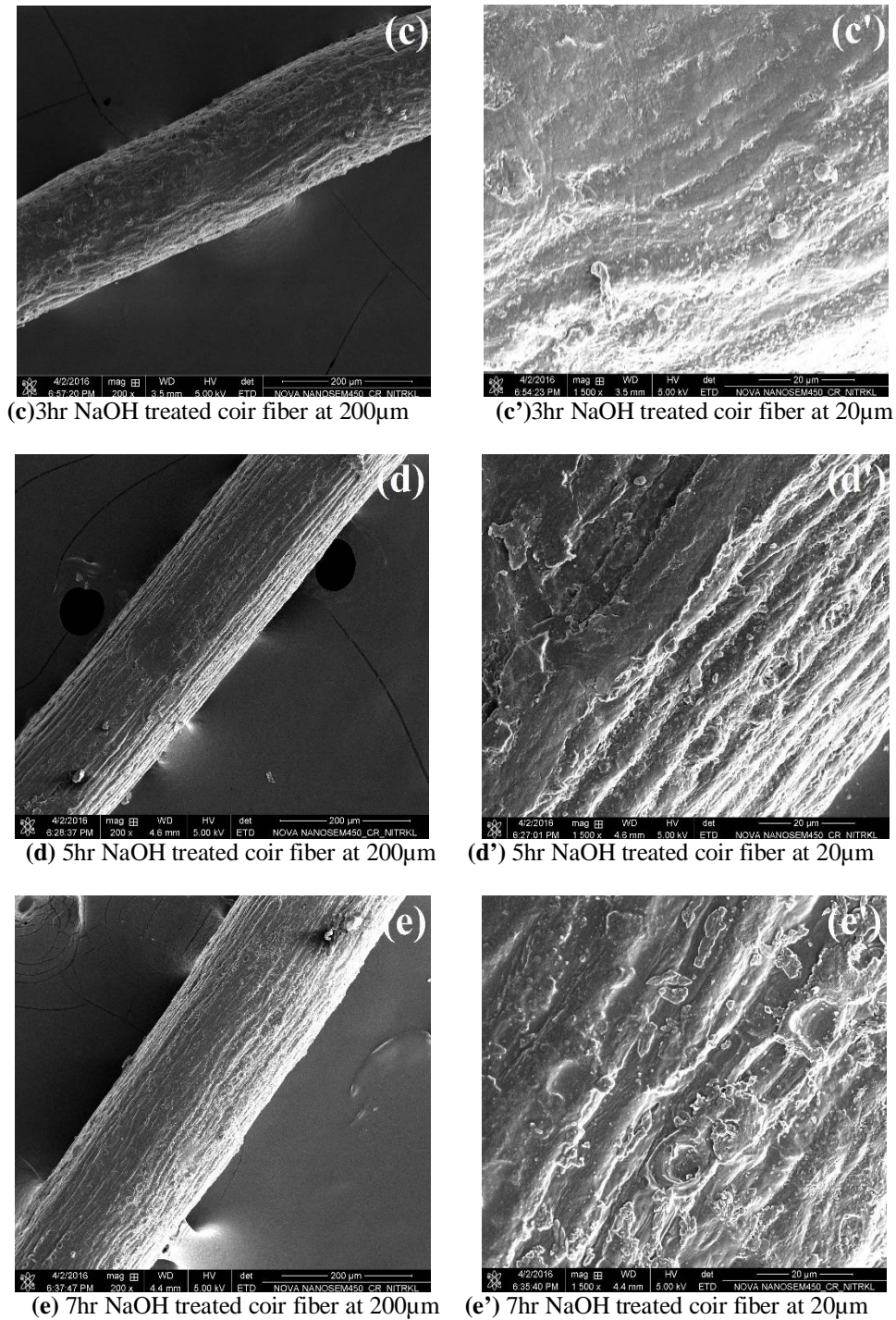


Figure 3.1. Surface Morphology of treated and untreated fiber

III-B.CHARECTERIZATION USING X-RAY DIFFRACTION

The XRD pattern of raw and NaOH treated coir fibers for 1hr, 3hr, 5hr and 7hr are shown in figure 3.2 and figure 3.3. In figure 3.4, 2θ with respect to different coir fiber has been shown. The diffractograms of both dewaxed and raw coir fiber shows a well-defined main peak around $2\theta = 25.5^\circ$, which is characteristic of cellulose. It has been seen that after dewaxing, 2θ is increasing up to 3hr NaOH treated coir fiber and decreasing after it. Inter planar spacing is decreasing up to 3hr NaOH treated coir fiber (more dense) and increasing after it. From the above it has been concluded that coir fiber is going through squeezing up to 3hr NaOH treated coir fiber and swelling happening after the 3hr NaOH treatment. Finally it confirms that crystallinity is more in case of 3hr NaOH treated coir fiber [11].

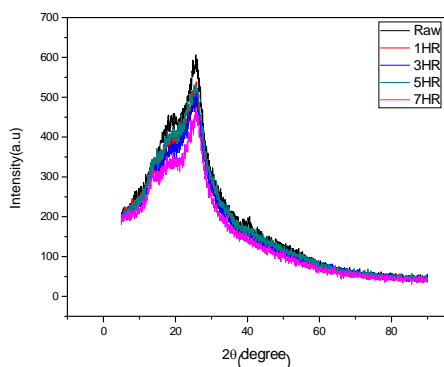


Figure 3.2. Diffraction pattern of coir fiber with different treatment

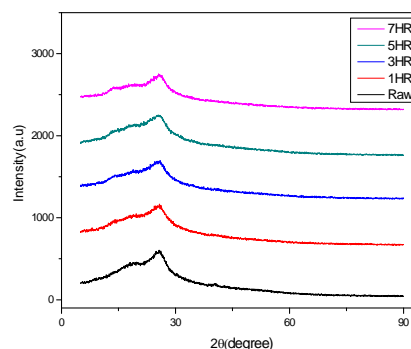


Figure 3.3. Diffraction pattern at peak position of coir fiber with different treatment

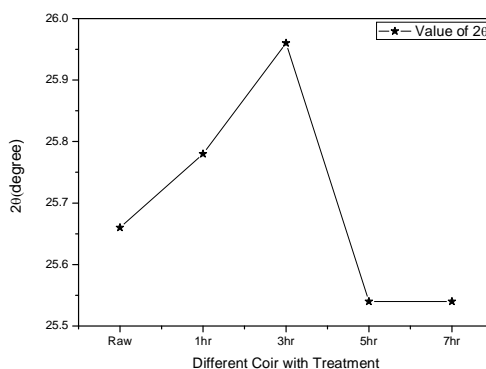


Figure 3.4. Value of 2θ for different coir fiber

III-C.FOURIER TRANSFORM INFRARED SPECTRA ANALYSIS

Wave number and their corresponding group has been shown for coir fiber in table 3.1.

Wave number(cm^{-1})	Corresponding Group
3406.87	(OH) broad, strong band from the cellulose, hemicellulose and lignin
2926.02	(C-H) in aromatic ring and alkane
1740.42	(C=O) most probably from lignin and hemicellulose
1610.96	(C=C) aromatic in plane
1516.54	(C=C) aromatic skeletal ring vibration due to lignin

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1473.71	(C-H);(C-OH) primary and secondary alcohol
1422.12	(C-H) primary and secondary alcohol
1370.53	(C-H) primary and secondary alcohol
1258.59	(C-OH) out of plane
1121.54	(C-O-C) stretching
1044.45	(C-OH) secondary alcohol
898.44	(C-O-C) in plane symmetry

Table 3.1. FTIR data analysis

FTIR analysis shows that OH stretching vibration (3406.87 cm^{-1}) is decreasing. The bond stretching for hydrogen bond at OH stretching and ester group C-O stretching appear at 3406.87 cm^{-1} and 1740 cm^{-1} respectively. A reduction in inter molecular/intra molecular hydrogen bonding among the hydroxyl group of cellulose ,hemicellulose and removal of hemicellulose upon alkali treatment results in decrease in the transmittance area ratio of both of these peak to the internal standard peak after alkali treatment. The aromatic bond of lignin band (1516.54 cm^{-1}) displays a decreased absorbed intensity ratio after dewaxing which confirms the decrease of lignin content in the dewaxed fiber. The presence of peak at 2950 cm^{-1} is due to the $-\text{CH}_2$ stretching vibration and its intensity increases up to 3 hour. There after it decreases up to 7hr which shows that at 3hr the $(-\text{CH}_2)$ bridging unit is maximum [12-14].

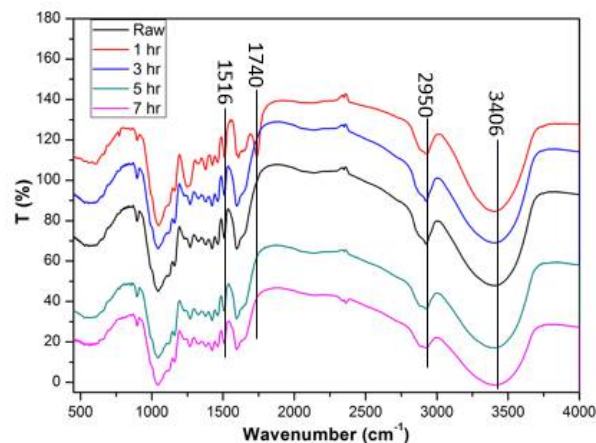


Figure 3.5. FTIR spectra of coir fiber with different treatment

III-D. FLEXUARAL STRENGTH ANALYSIS USING INSTRON

Flexural strength of composite prepared with raw coir fiber and treated coir fiber has been shown in figure 3.6. It confirms that flexural strength is highest for 3hr NaOH treated coir fiber. The interfacial zone plays a vital role in fiber reinforcement and which leads to transfer the load between fiber and matrix which consequently affects the mechanical properties such as strength. From surface morphology it has also been seen that interfacial zone was better in case of 3hr treated NaOH coir fiber. So it demonstrates that flexural failure depends mainly on the fiber and matrix adhesion. The increased value of flexural strength in case of 3hr NaOH coir fiber is due to the increase in effective surface area available for contact with the matrix. Impurities removed from the surface of 3hr NaOH treated coir fiber and replaced by epoxy in composite which creates an active bond with increased static force due to the rough surface of the coir fiber [11].

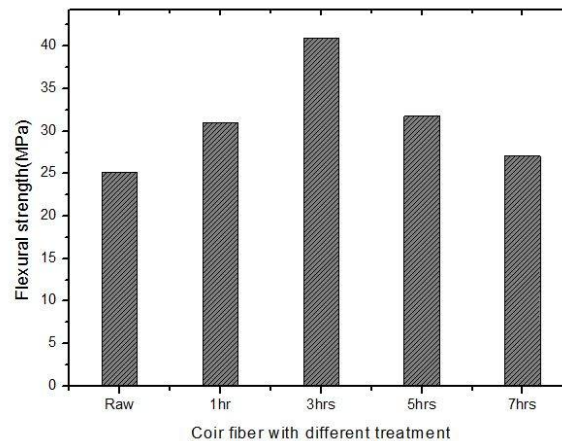


Figure 3.6. Flexural strength of coir fiber with different treatment

IV. CONCLUSION

On the basis of above work it has been found 3hr treated NaOH coir fiber is suitable for preparation of composite. From surface morphology it has been observed that adhesiveness is more in case of 3hr NaOH treated fiber which is suitable for bonding. 3hr NaOH treated coir fiber is maintain a proper surface roughness which leads to increase in the flexural strength of composite prepared with it. XRD analysis confirm that crystallization is increase up to 3hr NaOH treated coir fiber. NaOH treated coir fiber for a duration of 5hr and 7hr are going through swelling which leads to decrease in crystallinity. From FTIR spectroscopy it has been seen that amount of lignin content is decreasing in case of NaOH treated coir fiber. At the end it has been concluded that flexural strength is more in case of composite prepared with 3hr NaOH treated coir fiber. Overall it has been observed that chemical treatment can change the surface morphology. Proper surface roughness, adhesiveness always leads to increase in flexural strength of the composite. First and second treatment leads to increase in crystallization on the surface of the coir fiber, while third and fourth treatment creates trench groove on the surface of coir fiber. Coir fiber (3hr NaOH treated, physically at a temperature of 90°C for 5hr) is suitable for the composite preparation and better flexural strength.

V. FUTURE SCOPE

The researcher may study different mechanical strength analysis for the above work. Further, they can analyse the dielectric properties and water absorption capacity.

REFERENCES

- [1] D. Chandramohan and K. Marimuthu, "A review on natural fibers", *International Journal of Recent Research and Studies(IJRRAS)*, Volume 8, Issue 2, pp 194,2011
- [2] D. Verma1, P.C. Gope, A. Shandilya, A. Gupta and M.K. Maheshwari, "Coir fiber reinforcement and application in polymer composites", *A Review, J. Mater. Environ. Sci. Volume 4, Issue 2*, pp 263, 2013
- [3] M. Arsyad, I. Wardana, P. Patricio, Y. Irawan, "The morphology of coconut fiber surface under chemical treatment", *Revista Materia Volume 20, Issue 1*, pp 169, 2015
- [4] A. Moraes, M. Sirokoeski, S. Amico, "The novel use of sodium borohydride as a protective agent for chemical treatment of vegetables fiber", *Fibers and Polymers Volume 13, Issue 5*, pp641, 2012
- [5] C. Manikam, J. Kumar, A. Athijayamani, J. Samuel, "Effect of various water immersions on mechanical properties of Roselle fiber-vinyl ester composite", *Wiley online library Volume 10*, pp 1638, 2015
- [6] Samia S. Mir, Syed M. N. Hasan, Md. J. Hossain and Mahbub Hasan, "Chemical modification effect on the mechanical properties of coir fiber", *Engineering Journal, Volume 16, Issue 02*, pp 149,2012

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

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- [7] Annapurna Patra, "Macromolecular structure of sisal fiber and its potential applications", *PhD. Thesis*, 2012
- [8] P.N Khanam and M.A.A Almadeded, "Processing and characterization of polyhelene based composite", *Advanced manufacturing: composite and polymer science Volume 1*, pp 63, 2015
- [9] G.L Prasad, B.S.K Gowda and R. Velmurugan, "Prediction of flexural properties of coir polyester composite by ANN", *Mechanics of composite and multifunctional material Volume 7*, pp 173, 2016
- [10] K.Natarajan and Padma. C. Balasubramanya, "Mechanical and morphological study of coir fiber reinforced modified epoxy matrix composites", *International Journal of Emerging Technology and Advanced Engineering (IJETA)*, Volume 03, Issue 2, pp 583, 2013
- [11] Annapurna Patra and D.K Bisoyi, "Investigation of the electrical and mechanical properties of short sisal fiber reinforced epoxy composite in correlation with structural parameters of the reinforced fiber", *J. Material Science Volume 46*, pp 7206, 2011
- [12] P.R.L Lima, R.J Santos, S.R Ferrari and R.D.T Filho, "Characterization and treatment of sisal fiber residues for cement-based composite application" *Eng. Agric. Jaboticabal, Volume 34, Issue 5*, pp 812, 2014
- [13] B.W Jo and Sumit Chakraborty, "A mild alkali treated jute fiber controlling the hydration behavior of greener cement paste" , *Nature Publication, Volume 5*, pp 7837, 2015
- [14] A. Roy, B. Adhikari and S.B Majumder, "Equilibrium, Kinetic, and thermodynamic structure of azo dye absorption from aqueous solution by chemically modified lignocellulosic jute fiber" , *Ind. Eng. Chem. Res., Volume 52*, pp 6502, 2013
- [15] Haisong Qi, Jianwen Liu, Yinhu Deng, Shanglin Gao and Edith Mader, "Cellulose fibre with carbon nanotube networks for water sensing", *Journal. Mater. Chem. A Volume 2*, pp 5541, 2014
- [16] Shan M Assis, M Harishankar Nair, Anoop Khan P, Deepak S and Joji Oommen George, "Mechanical property evaluation of coir reinforced aluminum laminate epoxy", *International Journal of Applied Engineering Research, Volume 9, Issue 18*, pp 4857, 2014
- [17] Savita Dixit and Preeti Verma, The effect of surface modification on the water absorption behavior of coir fibers, *Advances in Applied Science Research, Volume 3, Issue 3*, pp 1463, 2012
- [18] A.K. Bledzki and J. Gassan, "Composites reinforced with cellulose based fibres", *Prog. Polym. Sci., Volume 24*, pp 221, 1999
- [19] Rakesh Kumar, Sangeeta Obrai and Aparna Sharma, "Chemical modifications of natural fiber for composite material", *Der Chemica Sinica, Volume 2, Issue 4*, pp 219, 2011
- [20] Girisha.C, Sanjeevamurthy and Gunti Ranga Srinivas, "Sisal/Coconut coir natural fibers – Epoxy Composites: Water Absorption and Mechanical Properties", *International Journal of Engineering and Innovative Technology (IJEIT)*, Volume 2, Issue 3, pp 166, 2012
- [21] U.S. Bongarda and V.D. Shinde, "Review on natural fiber reinforcement polymer composites", *International Journal of Engineering Science and Innovative Technology (IJESIT)*, Volume 3, Issue 2, pp 431, 2014
- [22] R. Hari Setyanto, Kuncoro Diharjo, I. Made Miasa and Prabang Setyono, "A Preliminary study: The influence of alkali treatment on physical and mechanical properties of coir fiber", *Journal of Materials Science Research Volume 2, Issue 4*, pp 80, 2013
- [23] Libo Yan and Nawawi Chouh, "Crashworthiness characteristics of flax fibre reinforced epoxy tubes for energy absorption application", *Materials and design Volume 51*, pp 629, 2013
- [24] J. Rout, M. Misra, S.S. Tripathy, S.K. Nayak and A.K. Mohanty, "The influence of fibre treatment on the performance of coir-polyester composites", *Comp. Sc. and Tech., Volume 61*, pp 1303, 2001