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# DEVELOPMENT OF NATURAL FIBER REINFORCED FULLY BIODEGRADABLE COMPOSITE ROD

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***Abstract:*** Green composites made from natural fibers are of great use in today's world. Many products of industrial use are made from these fibers and even the automobile sector is using these for making of body parts like panels, shelves, trim parts, brake shoes, engine transmission covers etc. and in terms of rods are like: Conductive cores for power transmission, Composite cables with optical fibers, Fishing rods, Golf club shafts, Tennis rackets and Competitive Bicycle paddle crank etc. The applications are not limited to these things only. Rather their scope and usage are increasing day by day. The advantage of using these green composites is that they are totally environment- friendly, light in weight, recyclable, good sound insulators and renewable. So, in this work, there is an effort to develop the fully green composite rods from the plant waste like banana leaves (chopped) and PLA pallets (green resin) which in turn tested for mechanical properties so that they can be applied in some applications as, on the basis of literature review, there exist some good mechanical properties of natural fibers which sustain them in required conditions. So it proves helpful for so many industrial and domestic applications that will be quite beneficial in making many other environment- friendly products in order to sustain our planet. So further it provides direction to the researchers for considering many other agricultural wastes for making of fully biodegradable composite rods.

***Keywords:*** Green composites, extrusion, rods, fibres, PLA

## 1. INTRODUCTION

A Composite is composed of two or more distinct phases (Continuous phase and Dispersed phase) and having significant bulk properties different from those of any of the constituent. The advantages of composite are like: having high Strength to weight ratio, Good Surface Finish, Low Thermal Conductivity, High Toughness, Electrical Insulation, Excellent Acoustic performance and Easy to handle.

Composites are classified on the basis of Matrix material (Fig. 2) and Reinforcement (Fig. 3).

The need of the green composites comes from the concept that Green composites are a special class of composite material where at least one of

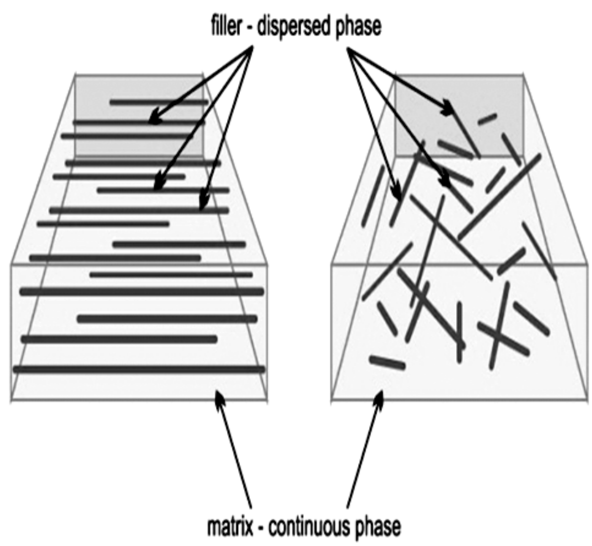


**Figure 1: Schematic of a composite [1]**

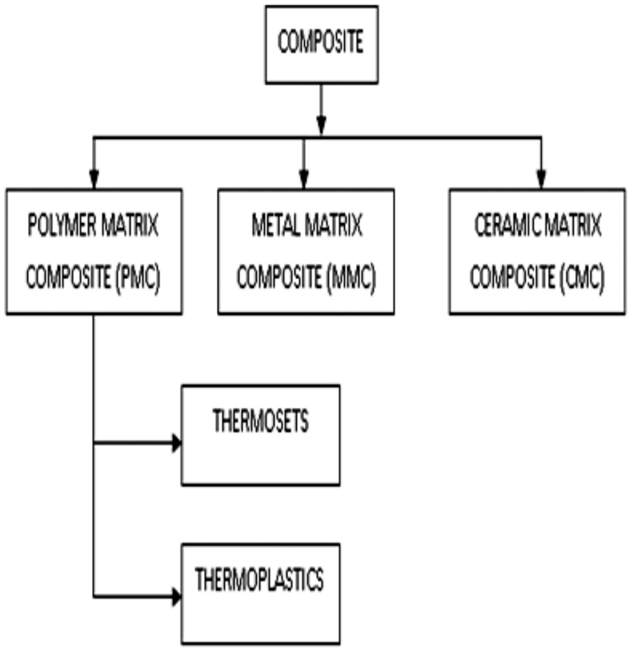


**Figure 2: Classification based on Matrix Material**

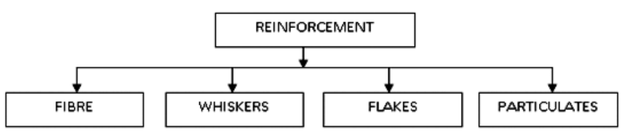


**Figure 3: Classification based on Reinforcement Material**

the components (matrix or reinforcement) is obtained from the natural resources where Matrix like PLA, Natural gums etc are used and reinforcement of natural fibers like Banana, Bagasse, Bamboo, Jute, Wool etc. Green composites are generally of two types, partially biodegradable and fully biodegradable. Global warming, the growing awareness of environment, waste management issues, dwindling fossil resources, and rising oil prices resulted in increased research in materials that are friendly to our health and environment. The most important advantage of natural fiber reinforced green composite is low cost, light weight, eco-friendly in nature [2], [3].

Some of the commonly used methods for development of composites are:

- Hand Layup Method
- Pultrusion Process
- Injection Moulding
- Compression Moulding

Natural fiber composites are being used in a wide range of applications like automobiles, construction, and furniture and so on. A rich application of plant fibers are in Mercedes-Benz E- class. Most of the parts of the car like center console and trim, various damping and insulating parts, seat cushion parts and door trim panels are made from plant fiber composites [2].

**Figure 4: Application of green composites in Automobile [4]**

## 2. LITERATURE REVIEW

Many researchers have worked on the development of natural fiber reinforced composites and improving on their mechanical properties. As our focus was to develop fully biodegradable green composite rods, so a brief survey has been perform in order to study the different fabrication techniques. Kocaoz et.al (2005) did tensile characterization of glass FRP bars and reports on a test protocol and the results obtained from a replicated experiment intended to yield a statistically valid estimate of the distribution of tensile strength in FRP bars [5]. Four selected types of glass FRP (GFRP) bars with the same diameter were tested. In total, 32 bars from the same manufacturer were investigated. Instead of a polymeric resin-based anchor, a steel pipe filled with expansive cementitious grout was used as the end restrainer. An experiment based on a randomized complete block design was carried out to obtain data for statistical analysis. The analysis was carried out using a commercially available data analysis software program. This research project indicates that the suggested test procedure provides reliable data for tensile characterization and confirms that a Gaussian distribution can represent the tensile strength of the GFRP bars as tested. Young et.al (2007) studied Hybrid effect on tensile properties of FRP rods with various material compositions to identify the material architecture for FRP reinforcing bars for concrete structures [6]. The effect of hybridization on tensile properties of FRP rods was obtained by comparing the results of tensile test for the hybrid rods with those of the non-hybrid rods. The result of the test program indicated that the ultimate strain of the hybrid rod was increased by up to 33%. Birks et al. (2009) investigated the Hybrid Composite Rods Subjected to Excessive Bending Loads i.e. glass fiber/carbon fiber/epoxy hybrid composite rods used in load bearing component of Aluminum conductor composite core/Trapezoidal wire (ACCC/TW) design by compression process and SEM [7]. It was found that smaller diameter mandrels induced larger axial stress state of the ACC core upon wrapping which affected the mechanical properties of the conductors in service. The ultimate compressive strength for the carbon fiber composite (724 ± 44 MPa) was greater than that of the entire ACCC (615 ± 62 MPa). Ahmadi et. al (2009) studied the mechanical properties of GFRP braid pultruded composite rods in three braid linear densities at three different braid angles (30°, 45°, 55°) [8]. It was found that braid pultruded rods had highest shear modulus when braid angle was 45° but tensile strength and flexural rigidity were found to be low. Sha et. al (2009) investigated the mechanical and thermal properties of chicken feather fiber/PLA composites to check the feasibility of using CFF/PLA composites in real life applications [9]. The tensile moduli of CFF/PLA composites with different CFF content (2, 5, 8 and 10 wt%) were found to be higher than that of pure PLA, and a maximum value of 4.2 GPa was attained with 5 wt% of CFF without causing any substantial weight increment. The morphology, evaluated by scanning electron microscopy (SEM), indicated that an uniform dispersion of CFF in the PLA matrix existed. Peng et.al (2011) studied the properties of natural fibre composites made by pultrusion process by focusing on the mechanical and morphological characterization of the pultruded composite rods made from hemp and wool fiber reinforcements [10]. The results showed that the composite using polyurethane resin system has higher specific tensile and compressive strength as well as the Young's and compressive moduli compared with the polyester and vinyl ester composites, while the polyester composite exhibits better flexural strength. Kar et al. (2012) performed the diametrical compression test on glass and carbon fiber composite rods [11]. Acoustic emission (AE) activity was recorded and images were acquired from the sample for analysis by digital image correlation (DIC). The apparent transverse modulus, plane shear modulus, and transverse tensile strength of the GF (glass fiber) rod were greater than that of the CF (carbon fiber) rod, and fracture surfaces indicated greater fiber/matrix adhesion in the GF system as compared to the CF system. Gamon et. al (2013) Investigated the influence of extruder screw speed and of total feeding rate was studied first on fibre morphology and then on mechanical and thermal properties of injected bio composites [12]. Increasing the screw speed from 100 to 300 rpm such as increasing the feeding rate in the same time up to 40 kg/h helped to preserve fibre length. Indeed, if shear rate was increased with higher screw speeds, residence time in the extruder and blend viscosity were reduced. However, such conditions doubled electrical energy spent by produced matter weight without significant effect on material properties. Sureshbabu et al. (2014) tested the carbon fiber/epoxy and glass fiber/epoxy pultruded rods for mechanical properties having 80% fiber loading and 20% matrices [13]. Three tests (tensile, chemical absorption and impact) at room and below room temperature were performed in which ultimate tensile strength of Glass/epoxy and carbon/epoxy was found to be 1041 MPa and 628 MPa at 41 kN and 25 kN respectively. In chemical testing of glass, maximum change was noticed in sulphuric acid and minimum in nitric acid. In carbon, maximum change was noticed in ammonium hydroxide and minimum in ferric chloride. During impact testing, carbon epoxy showed less strength than glass epoxy. Zamri et. al.(2015) studied the effect of different Kenaf Fiber Yarn Tex. Attempt has been made to produce kenaf ûbre-reinforced composites using the pultrusion technique [14]. The properties of the pultruded natural ûbre-reinforced composites are reported and compared. The ûbre sizes were adapted by varying the kenaf ûbre tex. The pultruded composite specimens underwent a hydrothermal aging study, to simulate the environments of outdoor structural applications. The results show that increased ûbre loading of the PKFRC improves the compression and textural properties, and the optimum result was at 70% v/v. The 1400 tex produced better compression and textural properties, compared to 2200 and 3300 tex. Athijayamani et. Al (2015) studied the effect of Reinforcement of Chopped Agave SisalanaVariegata/Banana Hybrid Fibers on the Mechanical Properties of Vinyl Ester Resin [15]. The research describes the mechanical properties of chopped agave sisalana variegata/banana hybrid fiber reinforced vinyl ester composites. Tensile and flexural strength of the chopped composites increased with fiber content. The tensile and flexural strength values showed an increase up to 40wt% and above that decreased. Tensile and flexural modulus increased up to 55 wt%. The 40 wt% fiber composite shows maximum tensile and flexural strength of 51.7Mpa and 57.6 MPa respectively. The maximum impact strength was observed with the composites having the fiber content of 40wt%. These results suggest that the optimum fiber content to obtain the maximum strength properties is 40wt%. From this brief literature survey, it has been concluded that natural fibers have wide scope in engineering applications despite having less strength than synthetic fibers. Despite having lower mechanical properties (lower density), lower weight proves useful while making panels of automobiles. Moisture absorption is overcome by some alkali treatments and by adding some synthetic resins to it. Therefore, in the pultrusion of rods, it has been concluded that rods can be made of natural fibers for the application where lower weight is required. Also, much can be done with some other thermal and chemical treatments. Above all, depending upon its applications, natural fibers are chosen by considering the required weight and strength of the final product.

## 3. RESEARCH GAP AND UNIQUENESS OF THIS RESEARCH WORK

As rods have so many industrial and domestic applications, research may prove quite beneficial for developing environment- friendly products in order to sustain our planet. After viewing literature surveys of Burks et al. (2009) and Kar et al. (2012), it is needed to make rods from the natural fibers at least for the products which do not require extreme mechanical strength. However the existing researches for making rods have made use of synthetic resins which are not bio-degradable. There is great scope for green composites using bio- degradable matrix and fibers if used in rods. So, in this work, there is an effort to make rods from the natural matrix like Poly lactic acid (PLA) and fibers like banana, bagasse etc. There is good scope of using these composites in some mechanical and electrical applications [16]-[18]. The existing efforts for making rods from composites have been made with pultrusion process but the fibers should be available in yarn form. There are some natural fibers (such as banana leaves, bagasse) which are not available in yarn form. The extrusion is being suggested as an alternative process in the proposed research so that more natural fibers can be utilised for making bio-degradable composites.

Till date many researchers did work on the making of composite rods but only with the help of pultrusion process. But for pultrusion process we need fibers in yarn form so that they can be pultruded after dipping in the resin. In other context researchers used the chopped fibers with PLA but only in injection moulding after mixing the PLA and fibers in twin screw extruder for making of sheets. Nothing has been done till date for the extrusion of rods from the PLA and chopped fibers with help of extrusion process. So with this one can able to fabricate any product with the help of extrusion by chopping any type of plant or animal fibers that can't be easily converted into fine yarns.

## 4. EXPERIMENTAL SET-UP DEVELOPED

A setup has been made for the development of green composite rods.

### 4.1. Treatment of Chopped fibers and PLA

First of all they are washed with distilled water at 60°C for 1 hour and then dried in air for 2 day. After that they are Immersed in 10% NaOH sol for 1 hr at room temperature. There after washed in distilled water. So after drying them at room temperature for 24 hours they finally dried in open sunlight for 1 day to completely remove the moisture from the chopped fibers. PLA pallets only dried in oven at around 70°C for 2 hours so that moisture removed completely.

### 4.2. Mixing of Material in Required Ratio

Material containing PLA and fibers is mixed properly in the required ratio in a container


**Figure 5: Single screw extruder for extrusion of rods**

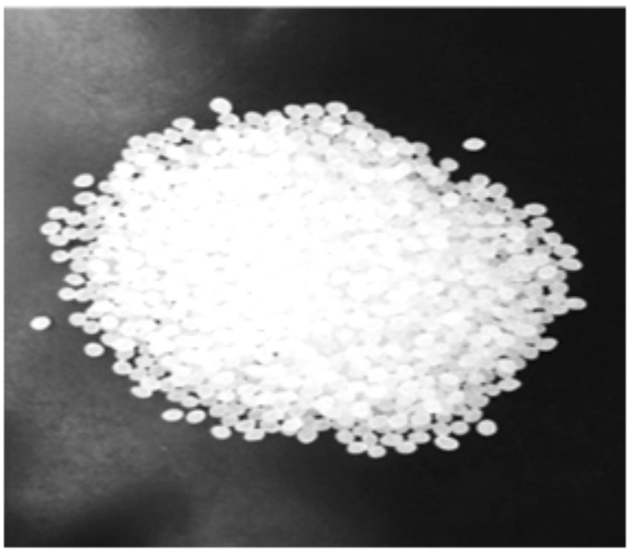

**Figure 6: Poly Lactic Acid in Granular form (3052D Injection grade)**

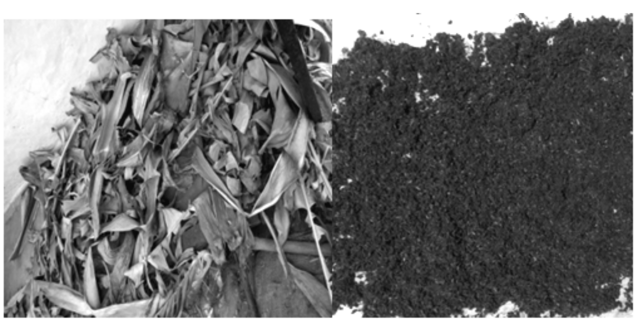

**Figure 7: Sunlight heat treated Banana leaves/stems and chopped banana fibres [a] Chopped fibers of Banana waste [b]**

considering the volume of the measuring glass. ASTM D7205 has been followed for making and testing of composite rods. Rod diameter taken is 9.5 mm. As per the process capability at the site, the length has been limited to 350 mm to 775 mm.

### 4.3. Developed Rod Samples

Different samples have been developed with different fibre fraction with PLA and also with single PLA, at barrel and die temperature of 105°C and 115°C respectively

## 4. RESULTS

As the work is going on so till date some tensile testings are done to check the strength of the developed rod. Tensile testing has been done on Computerised UTM of capacity 500 kgf (4.9kN) at Guru Nanak Dev Engineering College, Ludhiana.

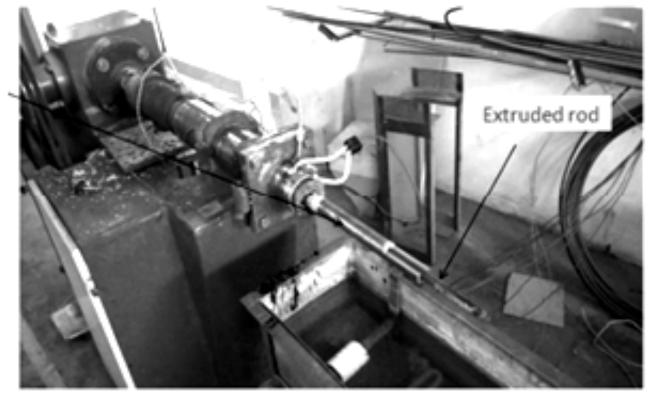


**Figure 8: Single screw extruder for extrusion of rods**

**Figure 9: Developed Green Rods. Only PLA (a) PLA and banana (b)**

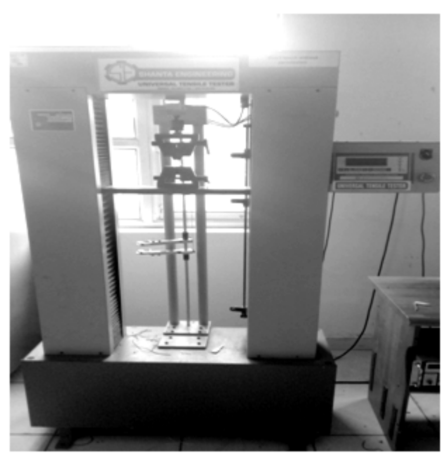

**Figure 10: UTM Machine**

Tensile testing has been done on different fibre fractions and PLA (v/v %)

**Table 1**
**Tensile Strength of Pure PLA Rod**

| *Sr No* | *Diameter (mm)* | *Area (Sq.mm)* | *Peak Load (N)* | *Strength at Peak (MPa)* |
|---|---|---|---|---|
| 1 | 9.65 | 73.10116 | 1076.78 | 14.73 |
| 2 | 9.45 | 70.10246 | 967.414 | 13.8 |
| 3 | 9.63 | 72.79847 | 1027.186 | 14.11 |

**Table 2**
**Tensile Strength of Composite Rod**
**(PLA 90% and Fibres 10% By Volume)**

| *Sr No* | *Diameter (mm)* | *Area (Sq.mm)* | *Peak Load (N)* | *Strength at Peak (MPa)* |
|---|---|---|---|---|
| 1 | 9.66 | 73.25274 | 1334.664 | 18.22 |
| 2 | 9.43 | 69.80604 | 1253.018 | 17.95 |
| 3 | 9.54 | 71.44410 | 1294.567 | 18.12 |

**Table 3**
**Tensile Strength Of Composite Rod**
**(PLA 80% and Fibres 20% By Volume)**

| *Sr No* | *Diameter (mm)* | *Area (Sq.mm)* | *Peak Load (N)* | *Strength at Peak (MPa)* |
|---|---|---|---|---|
| 1 | 9.55 | 71.59396 | 1570.055 | 21.93 |
| 2 | 9.78 | 75.08399 | 1681.881 | 22.4 |
| 3 | 9.68 | 73.55638 | 1641.043 | 22.31 |

**Table 4**
**Tensile Strength Of Composite Rod**
**(PLA 70% And Fibres 30% By Volume)**

| *Sr No* | *Diameter (mm)* | *Area (Sq.mm)* | *Peak Load (N)* | *Strength at Peak (MPa)* |
|---|---|---|---|---|
| 1 | 9.8 | 75.3914 | 2030.29 | 26.93 |
| 2 | 9.7 | 73.86065 | 1957.307 | 26.5 |
| 3 | 9.5 | 70.84625 | 1827.833 | 25.8 |

Further work has been going on to see the effect of more fibre fraction in extruded rod. And there after other mechanical properties and thermo mechanical analysis will be done to check the behaviour of the developed material under thermal and dynamic changes.

## 5. CONCLUSIONS

Tensile strength of only PLA comes out to be 14.73 MPa while in case of composite rod comprising of chopped banana fibres and PLA increase from 18.22 MPa to 26.93 MPa when fibre fraction increased from 10 to 30% by volume. So further research has been going on to check the level of fibre fraction at which there could be a maximum tensile strength. Here are some of the matters to be look after.

- Proper curing temperature should be maintained so that proper length according to ASTM standard could be extruded.

Flow rate should be optimum as per the cooling rate of extruded rod.

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## REFERENCES

[1] V.K. Thakur, "Green composite from natural resources", CRC press, Taylor and Francis.

[2] P.K. Bajpai, I. Singh & J. Madaan, "Development and characterization of PLA-based green composites: A review," J. Thermoplast. Compos. Mater., Vol. 27, 2012, pp. 52–81.

[3] F. P. La Mantia & M. Morreale, "Green composites: A brief review," Compos. Part A Appl. Sci. Manuf., Vol. 42, 2011, pp. 579–588.

[4] *http://www.globalhemp.com/2011/02/automotive-composites.html*

[5] S. V. Kocaoz, A. Samaranayake & A. Nanni, "Tensile characterization of glass FRP bars" Composites Part B: Engineering, Vol. 36, 2005, pp. 127–134

[6] Y.J. You, Y.H. Park, H.Y. Kim & Ji-Sun Park, "Hybrid effect on tensile properties of FRP rods with various material compositions", Composite Structures, Vol. 80, 2007, pp.117–122

[7] B.M. Birks, D.L. Armentrout, M. Baldwin, J. Buckley & M. Kumosa, "Hybrid Composite Rods Subjected to Excessive Bending Loads", Composites Science and Technology, Vol. 69, 2009, pp. 2625-2635.

[8] M.S.Ahmadi, M.S. Johari, M. Sadighi & M. Esfandeh, "An experimental study on mechanical properties of GFRP braid pultruded composite rods", Xpress polymers letters, Vol. 3, 2009, pp. 560-568

[9] S. Cheng, K.T. Lau , T. Liu, Y. Zhao, P.M. Lam & Y. Yin, "Mechanical and thermal properties of chicken feather fiber/PLA green composites" Composites Part B: Vol. 40, 2009, pp. 650–654

[10] X. Peng, M. Fan, J. Hartley & M. A. Zubaidy, "Properties of natural fiber composites made by pultrusion process", Journal of Composite Materials, Vol. 46, 2012, pp. 237-246

[11] N.K. Kar, Y Hu, B. Ahn & S.R. Nut, "Diametral Compression of Pultruded Composite Rods", Composites Science and Technology, Vol. 72, 2012, pp. 1283-1290

[12] G. Gamon , P. Evon & L. Rigal, "Twin-screw extrusion impact on natural fibre morphology and material properties in poly(lactic acid) based biocomposites" Industrial Crops and Products, Vol. 46, 2013, pp. 173–185

[13] Y. Sureshbabu, G. Naresh & S. B. Devi, "Experimental test on carbon fiber/epoxy and glass fiber/epoxy pultruded rods for mechanical properties" International Journal of Engineering Research, Vol. 3, 2014, pp. 135-139

[14] M. H. Zamri, H. M. Akil & Z. A. Mohdlshak, "Pultruded Kenaf Fibre Reinforced Composites: Effect of Different Kenaf Fibre Yarn Tex", Procedia Chemistry, Vol. 19, 2016, pp. 577-585

[15] A. Athijayamani, R. Ganesamoorthy & J. Gobinath, "Effect Of Reinforcement Of Chopped Agave Sisalana Variegata/Banana Hybrid Fibers On The Mechanical Properties Of Vinyl Ester Resin", International Journal of Mechanical Engineering and Research, Vol. 5, 2015, pp. 20-23

[16] Chandramohan & K. Marimuthu, "A Review on Natural Fibers", IJRRAS, Vol 8, 2011, pp. 194-206.

[17] http://www.bcomp.ch/40-0-sports-und leisure.html

[18] http://www.ufpt.com/materials/natural-fibers.html