A STUDY ON PROPERTIES OF NATURAL FIBRES - A Review

K. Arun Kumar[1] , S. Madhu Sudhanan[2], K. Mahesh Kumar[3], G. Ranjith Kumar[4]

[1]*Assistant Professor, Mechanical Engineering, Sri Ramakrishna Engineering College, Coimbatore*
[2,3,4] *Students, Department of Mechanical Engineering, Sri Ramakrishna Engineering college, Coimbatore*

Abstract - *Growing towards the eco-friendly technology natural fibres takes main part in the field. This study is about discussing the properties of natural fibre and natural fibre composites. Influence of various factors like fibre diameter, fibre content, density, fibre size, geometry of fibre and coupling agents towards the mechanical properties, thermal properties and water intake properties are presented in this study. Improvement on Surface treatment and addition of coupling agents can improve the property which is low. These techniques improve the mechanical properties, thermal properties and water absorption properties.*

1. INTRODUCTION:

Over the last decades, natural fibres received increasing attention as alternative to synthetic fibres both from academic world and various industries. There is a variety of different natural fibres, which can be used as reinforcements of polymer (i.e. thermosets and thermoplastics) composites. Four main reasons make the natural fibres more attractive than others: i.e. specific properties, price, biodegradability and recyclability. Particularly, high specific and low density properties are nice benefits. Other than this, they are renewable and have a CO_2 neutral life cycle, compare to their synthetic competitors (i.e. carbon and glass) [1, 2].

Driven by the introduction of regulatory norms demanding more environmental-friendly products, the use of natural fibres as reinforcements for composites materials has increased significantly in the last decade [3]. Natural fibres such as flax, jute, hemp and kenaf offer low carbon footprint and biodegradability advantages combined with a high specific strength and stiffness at a low-cost [4-6]. The application of natural fibres is motivated by a combination of environmental sustainability, cost-effectiveness, recycling and biodegradation properties [7]. Natural fibres are used as reinforcement in structural applications in automotive industry. Natural fibres such as hemp and flax are used to manufacture door panels and the roofs of cars [8].

Fibre reinforced polymer composite materials have played an important role in a variety of applications. As a result of the increasing environmental awareness, the concern for environmental sustainability and the growing global waste problem is increased year by year. Fibre-built polymer matrix composites are finding applications in households and industries because they have more favourable properties such as high stiffness, greater strength, better fatigue performance, more corrosion resistance, low thermal expansion, low energy consumption during manufacturing and have non-magnetic properties. Epoxy resin and its composites have received considerable attention over the years for their use as structural materials at low temperature.

2. TYPES OF PLANT BASED NATURAL FIBRES:

2.1. Bast fibre

Bast fibres are usually extracted from the outer bark of plant stems. Some examples of bast fibres are jute (Corchorus olitorius/ Corchorus capsularis), flax (Linum usitatissimum), abaca (Musa textilis), and kenaf (Hibiscus cannabinus). Retting is the process through which these bast fibres are extracted, and is accomplished through biological or chemical degradation of cut plant stems.

2.2 Leaf fibre

Leaf fibres are coarse and hard fibres obtained from leaf tissues by hand scraping after beating/retting process or mechanical extraction. Owing to the relatively high strength, leaf fibres are typically used for the production of ropes, fabrics, carpets and mats. Examples of leaf fibres are sisal, caroa, henequen and pineapple.

2.3. Seed fibre

Coir fibre is a typical example of seed fibre, and it is extracted from the coconut husk. These lightweight and strong fibres are mainly used in the production of ropes, mats, sacks, brush, geotextile and etc. Another set of seed fibres are also extracted from the pod or boll of some plant seeds. Examples are cotton and kapok.

2.4. Stalk fibre

These are fibres from plant stalks, and are typically extracted from plants such as sugarcane, corn, eggplant, sunflower, wood and the straw of various grain crops such as barley, wheat, rice and etc. Pulp from some of these fibres has been utilized in paper and paperboard products.

2.5. Grass and other fibre crop residue

Widely available tall grasses such as ryegrass (Lolium perenne), elephant grass (Pennisetum purpureum), switchgrass (Panicum virgatum) and bamboo (Bambusa vulgaris) are important sources of fibres. Fibrous crop residues such as pulse seed coat, peanut shell, hazelnut husk, corn husk, millet stover, and etc. can potentially be used as fibre reinforcements in cement-based composites.

2.6. Wood and specialty fibres

Wood fibres are sourced from a wide variety of trees. Hence, they are in abundant supply across the world. Wood fibres are broadly divided into two groups, softwood and hardwood. The major difference between these two groups is that while softwood fibres are generally longer than hardwood fibres [9].

3. NATURAL FIBRE'S PROPERTIES:

3.1 MECHANICAL PROPERTIES:

The kenaf, jute, and hemp yarns that were to produce the woven fabrics were prepared. The EpoxAmite 100 series resin was selected as the polymer matrix, and it was mixed with a hardener in a ratio of 3:1 to form the binder for the composite preparation. For tensile testing, dog bone specimen used using a Dremel 4000 tool and it was performed using a 100 kN universal testing machine. Results (Fig 1) indicate that the incorporation of a high strength kenaf fibre with the jute and hemp fibres enhanced the ability of the interwoven hybrid composites to resist breaks and deformation under a tensile load, in comparison with the individually woven composites [10].

Sisal plants were prepared. Some portions of cleaned fibres were soaked in 10 wt% $NaHCO_3$ solution for 24 h, 120 h and 240 h at room temperature, then washed with distilled water and dried in an oven at 40C for 24 h. Tensile test was conducted in UTM . It is possible to observe that the values of both Young's modulus and tensile strength increase with increasing the treatment time up to 120 h. After 120 h of treatment, Young's modulus keeps increasing whereas tensile strength of the treated fibres begun to decrease. This may be due to degradation phenomena which occur if the treatment time is too long [11].

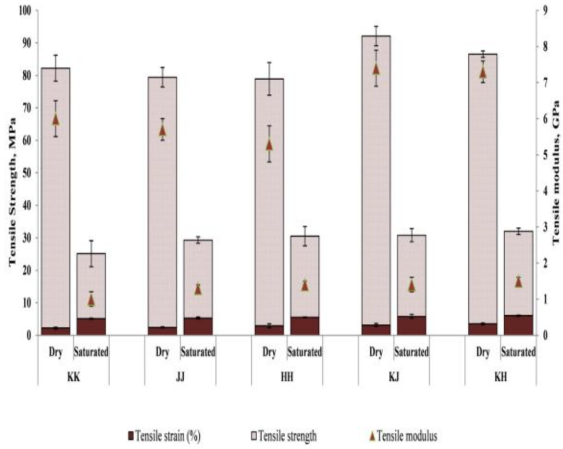

Fig1-Tensile properties of various woven composites in dry and saturated condition

Agricultural fibres retrieved after the crops harvesting called agro fibres. Agro-fibres are bonded with bioplastics called Agro-Plastics. Prototypes are made for TRAshell, Plant Culture. It is bonded with a bio-based epoxy resin through a closed molding process. Plant culture is composed of agro-fibres compounded by a bio-based thermoplastic matrix (PLA bioplastic). Test was conducted on Uni-axis tensile test with the same specimen size. The E-Modulus and tensile strength properties are described in the Fig 2. From the figures, it is clear that Plant Culture has shown the highest performance in comparison to others [12].

Two natural fibres extracted from fruit (borassus) and bast (ramie) were mechanically characterized. A commercial grade of PCL (Capa 6500) used as matrix. Fibres were treated in a sodium hydroxide solution (5%w) for 4 h at room temperature. 10, 20 and 30 wt% amounts of natural fibres were tested on a Zwick/Roell Z010 equipped with a 200 N load cell. Results reported that the addition of ramie fibres results in a significant increase in both tensile strength and Young's modulus of the composites compared to the neat matrix. A slightly different behaviour is presented by borassus fibres that did not cause an improvement of the strength over that of neat PCL (Fig 3) [13].

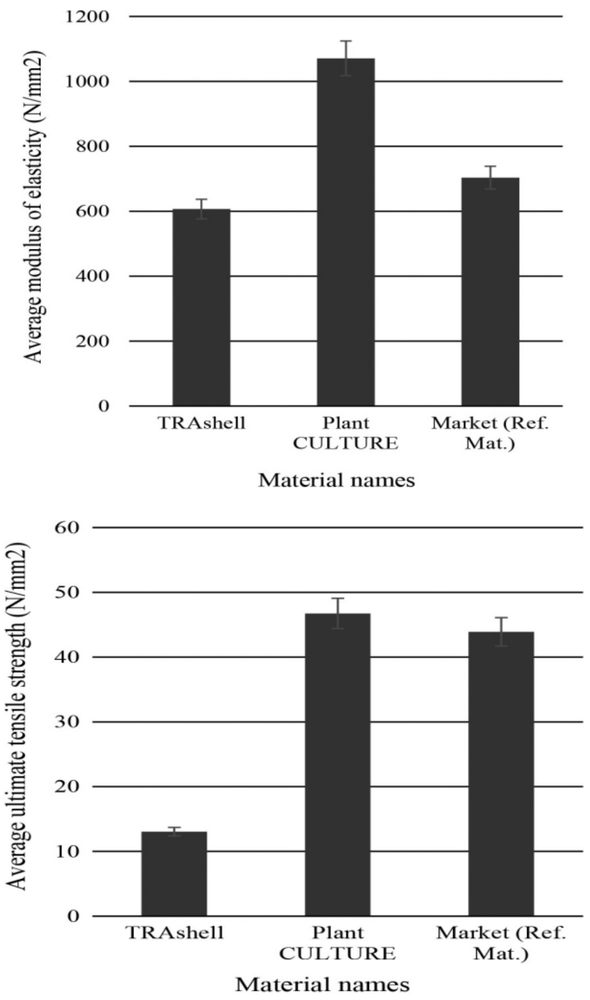

Fig 2- Comparison of Composite Materials- Ultimate strength and Elastic modulus

Fully bio-based thermoplastic composites are manufactured with bio-based polyethylene(85%) (From sugarcane) and short fibre coming from Cortaderia selloana (CS) wastes. Fibres were in the 1-4mm range. Cortaderia selloana fibers treated in a 15 wt% NaOH solution. Tensile and flexural properties of the different samples of bio- HDPE/CS were measured with a universal test machine with a load cell of 5 kN. From results (Fig 4) the fibre content increases, both the tensile and flexural modulus increase [14].

Epoxy matrix was mixed with a mechanical stirrer with 2.5, 5, 10 wt% of basalt powder respectively to the total weight. The compositions were mixed with curing agent Z1[tri ethylene tetramine]. The epoxy composites were fabricated in a mold using hand layup method. Tensile mechanical properties were measured with INSTRON 4481 universal testing machine with a load cell of 50 kN. In all cases from results found that basalt filler introduction led to an increase of the elasticity modulus of the composites and a reduction of their elongation at break. Introduction of higher amounts of the powder may cause formation of (defects) in epoxy matrix [15].

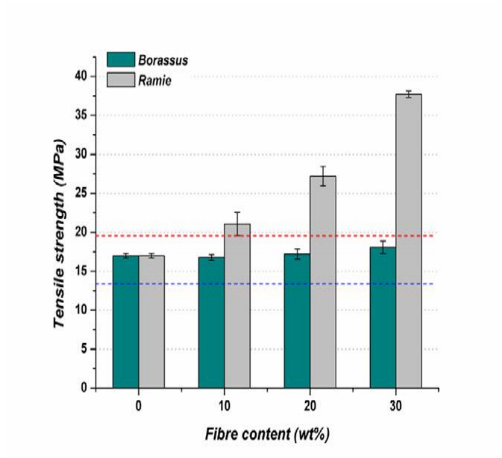

Fig 3 - Tensile strength for composites reinforced with borassus and ramie fibres

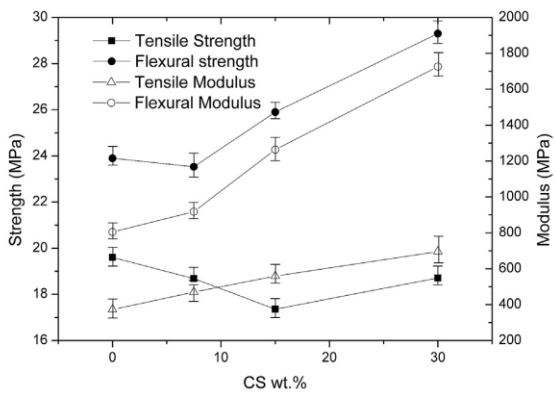

Fig-4 Mechanical properties of bio-HDPE/CS composites in terms of the wt% of Cortaderia

Cement masonry blocks reinforced with lechuguilla natural fibres, that were lightened with polyethylene terephthalate. A concrete mix was designed for a target compressive strength of 16 MPa at 28 days. Masonry concrete blocks were produced for two different fiber lengths (25 and 50 mm) and with fiber contents of 0.25%, 0.50%, 0.75% and 1.0%. Based on the obtained results, it was found that as the aspect ratio decreases the compressive strength increases [16].

Natural Hemp Fibres are taken. The short length hemp fibers treated with 5% NaOH (THF) were sandwiched in bisphenol A-aniline based benzoxazine (BA-a) to form the resin-fibre-resin composite. It was detected that with increase of fiber content from 0 to 25 volume % Tensile strength gradually increases. Addition of 25 vol % THF doubles the Tensile Strength of composite as compared to poly(BA-a) (Fig 6) [17].

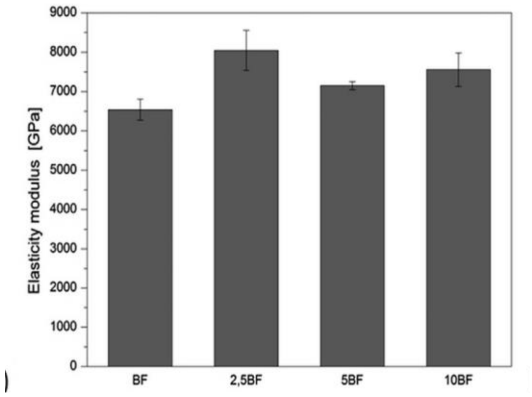

Fig-5 Mechanical properties of composites

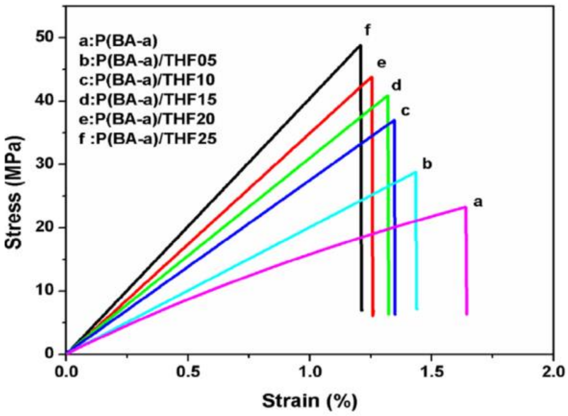

Fig-6 Stress strain for THF content

Basalt fiber (BF) was used to reinforce polylactide (PLA) to obtain new composites with potential structural or engineering applications. The tensile strength and modulus increase with increasing BF loadings. 20 wt% BF can increase the strength and modulus by about 30% and 47% respectively (Fig 7) [18].

Composites with different volume fractions (30, 40 and 50 volume %) were confectioned by laying the fibres in a steel mold and pouring liquid resin epoxy under pressure of 3 MPa. The specimens were dried for 24 h at room temperature and then tested in an universal Instron tensile testing machine. From results the presence of eucalyptus fibres did not affect the tensile strength but increased the elastic modulus of epoxy matrix composites. Indeed, the value of elastic modulus increased approximately 50% for epoxy matrix composites [19**]**.

Sisal Fibres are taken to study the effect of the alkalinity of pore solution on fibre degradation metakaolin (MK) with 10 wt% (MK10) and 30 wt% (MK30). The specimens were demolded after 24 h and immersed in pH-saturated water at 23±2 °C for 28 days prior to accelerated aging treatment. Stress–strain curves obtained by uni-axial tensile testing of selected sisal fibres. It can be seen that the tensile strength of the embedded fiber in MK30 after 5 wetting and drying cycles is slightly higher than that of a raw fiber. It is caused by the removal of non-cellulosic materials and impurities [20].

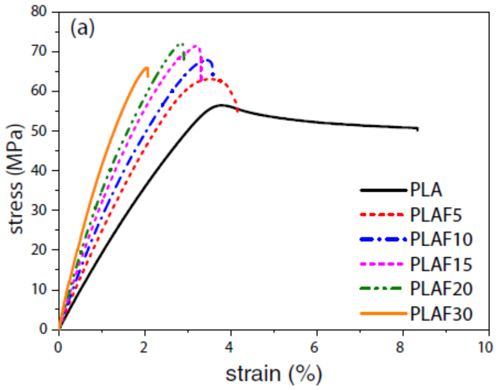

Fig-7 Stress Strain curve for PLA & PLABF

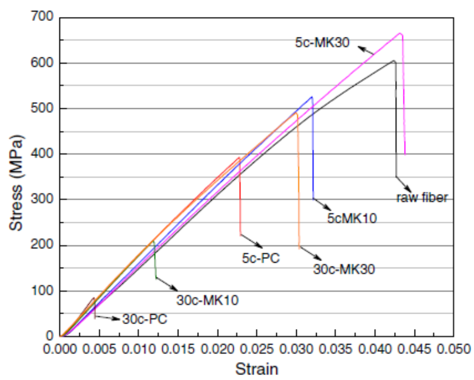

Fig-8 Stress–strain curve of tensile test on sisal fibres

Sisal fibres are prepared. Sisal fibres are treated by Hornification, Alkali treatment, Polymer impregnation, Hybrid treatment. The tensile tests were performed in an electromechanical testing machine with a load cell of 1 kN. For alkali treatments the tensile strength of sisal fiber was improved by 32%. Reason of the increment in the tensile strength and elongation is the removal of non-cellulosic materials and impurities. The treatment with polymer and hybrid increased 50 % and 60 % tensile strength (Fig 9) [21].

Natural fibre composite plates are made from hemp, flax and jute fibres are subjected to pure compression.

Epoxy resin is used for composition. The buckling and post-buckling responses are stable and the final condition is reached in a predictable and stable manner .From Fig 10 Jute have high tensile strength and Flax have high elastic modulus. From results this natural fibre composite sections can be used in light structural applications such as in the residential and light commercial markets [22].

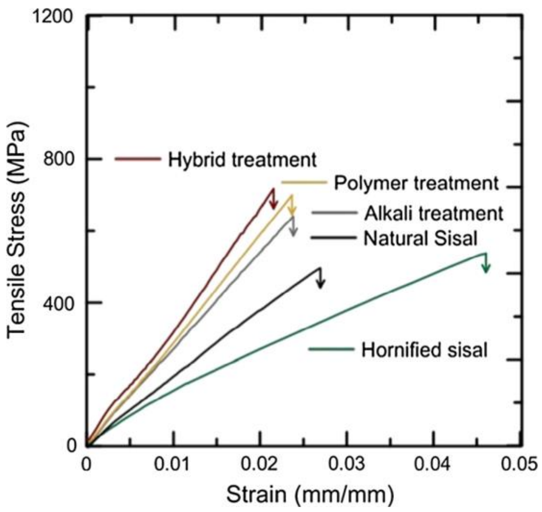

Fig-9 Influence of fibre treatments on the sisal fibre tensile behaviour

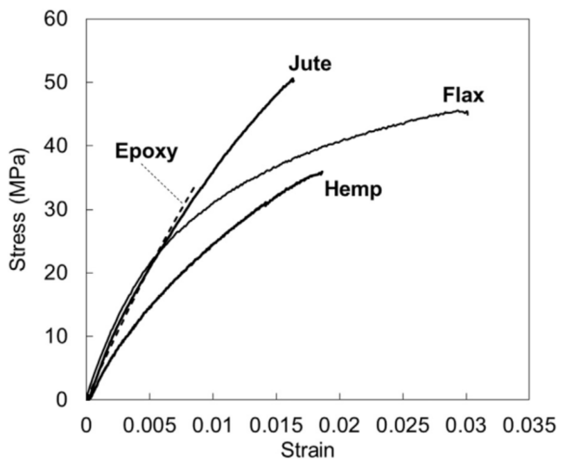

Fig-10 Stress Strain Curve for Fibre composites

Short fibres (1-4mm) from Cortaderia selloana (CS) wastes are collected. These fibres are treated with bio-based polyethylene compounds like maleic anhydride, hydrophobic silane, Sodium hydroxide and alkali treatment. Mechanical properties evaluated by impact and tensile tests. Addition of fibre (30%weight) increases the stiffness while Tensile strength not affected but gradually increased. But elastic modulus increased twice for 15-20% fibre content (Fig 11) [23].

Coir fibres are taken for alkali treatment. These coir fibres are reinforced with epoxy [CFRE]. Then CFRE treated with 5% weight NaOH solution for 30 min at 20 C. Mechanical properties of CFRE were determined by tensile test on the Instron 5567 machine. Alkali treatment improved the tensile and flexural properties. From results found that 16.7% and 17.8% growth in flexural and tensile strength respectively [24].

Coir fibres are taken from husk as hydrated and dehydrated form. Tensile test was carried out on horizontal environmental micromechanical tester (max 450g). From results (Fig 12) that dry fibres have higher strength than the wet fibres. Fibre diameter is larger in Wet specimen [25].

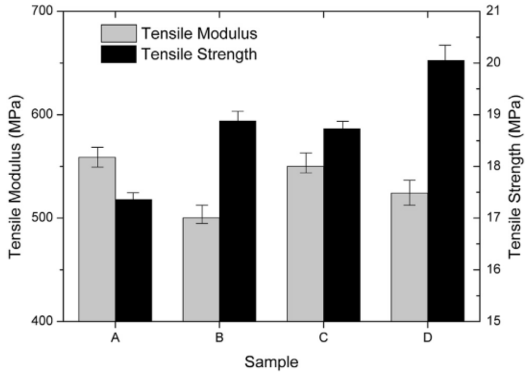

Fig -11 Tensile Properties

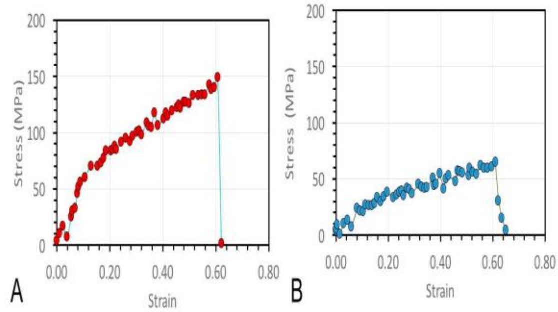

Fig-12 Stress Strain Curve for Dry (a) and Wet (b) Specimen

From herbaceous plants [family-musaceae] banana fibre is obtained. Flax fibre is obtained from family linaceae. Epoxy and Hardener is used in the ratio of 9:1. Fabrication process is made by sandwich method. By hand layup method one layer of banana fibre is sandwiched between two flax fibre layers. The result (Fig 13) shows that hybrid composite has better properties than other single fibre glass reinforced composites under flexural and impact test. It is found that the hybrid composite have high strength than the single fibre composites [26].

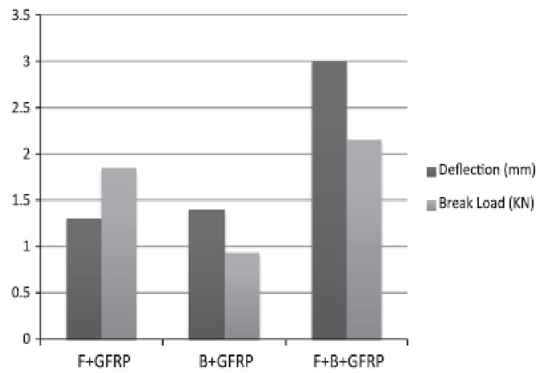

Fig-13 Comparison of Break Load, Maximum Deflection

Banana fibres are obtained from plant. Polypropylene (PP) and maleic anhydride grafted polypropylene (MAPP) are mixed in the weight ratio of 95% and 5% respectively. Composites are prepared in the ratio of 70:30 for PP and fibre respectively. Tensile test was conducted on Universal Testing Machine (5kN) for five specimens at temperature of 25°C. From results (Fig 14) that PP/Banana yarn composite have the highest improvement on tensile strength, which is 294% from others [27].

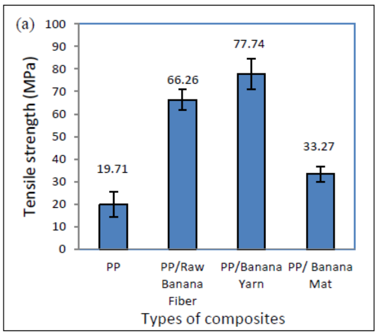

Fig-14 Bar chart of Tensile strength

3.2 THERMAL PROPERTIES:

Thermal insulated materials based on natural fibres are currently high on construction market. Hemp-based insulated materials are taken. These samples should not contain more than 20% of weight content. Specimen made by bi-component bonding method (air-lay) with the addition of 15% of polyester bi-component fibres. From result (Fig 15) it is found that Increase in Density will decreases the Thermal Conductivity [28].

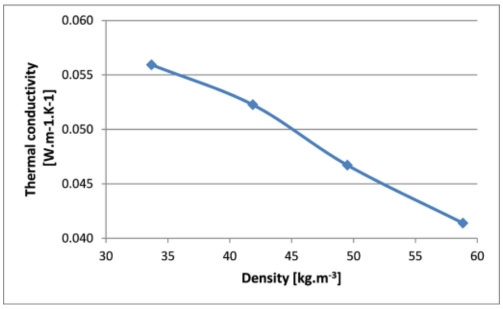

Fig-15 Graph plotted between Thermal conductivity and density

Coir fibres are prepared and washed in water. Then it kept in 1.6 mol/L NaOH solution for 48 Hours. Polypropylene(PP) is used as reagent with a density of 0.9 g/cm3. Using thermo gravimetric analysis(TGA) thermal stability was evaluated. From results show that the alkali treatment enhances the thermal stability of the fibres from 324/449°C to 331/474°C,by elimination of non-cellulosic compounds on the fibres surface(Fig 16) [29].

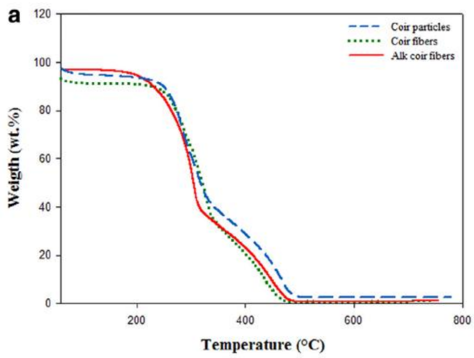

Fig-16 TGA of treated and untreated coir fibres

3.3 WATER INTAKE PROPERTIES:

Jute Fibre is selected for this process. Initially fibre is treated with 18% NaOH to increase mechanical properties. Epoxy resin is used by hand layup technique using compression moulding machine. Specimens are immersed in distilled water. It is carried out 28 days. From results NaOH treated fibre takes less moisture content [30].

Ijuk fibres are prepared and cut about 2mm. Then washed in water and dried in oven for 24 hours at 65°C. Then fibres are silane treated with Vinyltrimethoxy silane. Composite fabrication is done using roll mill mixer. Intake proportions are found from final and initial weights after and before immersion in water for 24 h. From results (Fig 17) it was found that Water absorption increases at higher fibre content and also there was less difference in treated and untreated fibre [31].

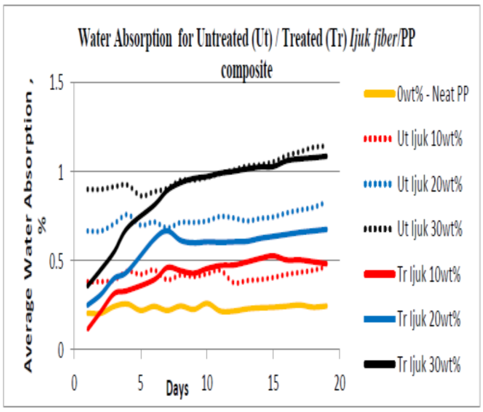

Fig-17 Water absorption for Fibre composites

4. CONCLUSIONS:

Natural fibres and natural fibre composites can be used in engineering applications because of their environmental suitability and Economic. Now a days lot of new composites are generated and technical and economical issues are noticed. Natural fibre/ Natural fibre reinforced epoxy composites with high durability and effective mechanical properties were developed in the last decade. The main challenges for the near future are to further improve the durability and the mechanical performance of these composites by decreasing the costs of fabrication while developing an eco-friendly strategy. Blending of fibres is also a better option for improvement the mechanical and thermal stability of the natural fibre reinforced epoxy composites. Various treatments, various resin and various coupling agents are used to increase the mechanical properties among these alkali treatment and epoxy resin is widely used and economically successful.

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