

FABRICATION AND CHARACTERIZATION OF EPOXY COMPOSITES REINFORCED WITH NATURAL FIBERS

S. BHANU PRAKASH¹, M. SANTOSH KUMAR², K. MANIKYA JAGADEESH³, P. VENKATESH⁴, D VANITHA⁵, V K VARDHINI⁶.

1.2.3.4 Student, Dept. of Mechanical Engineering, Avanthi Institute of Engineering and Technology,
Makavarapalem, Anakapalli (Dt), Ap.

5,6. Assistant professor, Mechanical Engineering, Avanthi Institute of Engineering and Technology,
Makavarapalem, Anakapalli (Dt), Ap.

ABSTRACT

Natural fiber-reinforced polymer composites have gained considerable attention in recent years due to their lightweight nature, renewable origin, low cost, and potential to replace conventional synthetic fiber composites in various engineering applications. The present work focuses on the fabrication and mechanical characterization of natural fiber-reinforced epoxy composites using hemp, palm, and pineapple fibers. These natural fibers are selected as reinforcement materials, while epoxy resin and hardener are used as the matrix system to produce composite specimens with different fiber weight percentages.

The fabrication process involves the collection, cleaning, chemical treatment, drying, and cutting of natural fibers to the required dimensions. The fibers are treated with sodium hydroxide (NaOH) solution to improve their surface characteristics and promote better bonding between the fibers and the epoxy matrix. The treated fibers are mixed with epoxy resin and hardener and fabricated into composite specimens for mechanical testing. The prepared samples are evaluated based on density, microhardness, tensile strength, flexural strength, and impact resistance. The experimental investigation aims to examine the influence of fiber type and fiber weight percentage on the physical and mechanical properties of the developed composites.

The comparative analysis of hemp, palm, and pineapple fiber-reinforced epoxy composites can help identify suitable natural reinforcements for lightweight and sustainable engineering applications. These composites have potential uses in automotive components, furniture, construction materials, and other non-structural applications. The study supports the development of environmentally responsible composite materials by utilizing renewable natural resources. The final assessment of the performance of each composite will be based on the experimental results obtained from the mechanical tests.

Keywords: Natural fiber composites, hemp fiber, palm fiber, pineapple fiber, epoxy resin, NaOH treatment, tensile strength, flexural strength, impact resistance, microhardness.

1.INTRODUCTION TO COMPOSITE MATERIALS

In the last few years, there has been a stringent consumer's awareness towards new products from renewable sources. Green marketing, new directives on recycling, social influence and change of cognitive values have led the consumer towards environmentally friendly products. In particular, composite materials are being developed and redesigned aiming to improve and to adapt traditional products and introduce new products in a sustainable and responsible way. The context of fibers-reinforced bio-composite materials while providing an insight about natural fibers for bio-composites, with the focus on properties and their applications. Natural fibers are mainly either plant or animal sourced. The first is essentially comprised of cellulose, whilst the latter is protein-based. However, in the composites industry, natural fibers are often referred to as vegetable fibers. One of the issues of natural fibers is the scattered information and the differences in mechanical properties reported. Also, the lack of

standards for both producers and users of these materials regarding methods to collect, treat, process and post-process natural fibers adds to the complexity of selection. These issues are in fact, critical deterrents for generalized use of natural fibers in different applications. To address this gap a review of different mechanical properties of natural fibers and their applications is presented[1].

Natural fibers like sisal, banana, jute, oil palm, kenaf, recycled jute and coir have been used as a reinforced composite for advanced applications such as aircraft and aerospace structures and for ordinary applications like consumer goods, furniture, low-cost housing and civil structures. The incorporation of stiff fibers in soft matrices can lead to new materials with outstanding mechanical properties encompassing the advantages of both the fiber and matrix. Fiber-reinforced composites are strong stiff and lightweight materials that consist of strong, stiff, but commonly, brittle fibers encapsulated in a softer, more ductile matrix material. The matrix transmits applied loads to the reinforcing fibers within the composite, resulting in a material with improved mechanical properties compared to the un-reinforced matrix material. Since the early 1960s, there has been an increase in the demand for stronger, stiffer and more lightweight materials for use in the aerospace, transportation and construction industries. In recent years, natural fibers appear to be the outstanding material which has emerged as a viable and abundant substitute for the expensive and nonrenewable synthetic fiber[2-3].

Recent days, the demand for technology has been on the use considering the developments seen in the future generation. Hence, a decent product which satisfies consumers require should be of prime quality and cost effective.

At present, engineering materials like nano materials, smart materials and meta materials dominate the sector. In recent years, a large number of materials have come into existence. These include polymers, metals, ceramics and composite materials. Considerable work has been initiated in the area of material science[4].

Composite materials are the newest trends showing major developments in material technology. They demand high importance and impact in industries. They have combined properties of reinforcement and matrix. A hybrid structure is light in weight, stable, eco-friendly, non-corrosive and has many more favorable properties.

Polymers have an outsized variety of demands in areas of glass, carbon and aramid fibers. Normally, the fibers are organized in uni,bi and multi-directional. Polymers are mainly classified into two types. They are thermoplastics and thermosetting plastics.

Thermoplastic materials found use in all fields due to their important structural characteristics. Thermoplastics include acrylics, nylons, polycarbonates, polyvinylchloride, etc. Thermosetting plastics include polyester, phenolics, polyamides, vinyl esters, bismaleimide, epoxies, etc.

1.2 HISTORY OF COMPOSITES

In 4000 BC, Egyptians used fiber composites from papyrus plant as writing material. Around 3400 BC, glued wood stripes were used as composite, a material well known for making laminate for commercial use.

Around 1500 BC, ancient Egyptians used straws for reinforcements in mud bricks to construct in pottery and boats. In 1200 AD, Mongolians made composite materials with a combination of wood, bone and glue. These were employed for making bows, which were extremely strong[5].

In 1870's, polymerization process was developed which allowed new resin for part transformation during a chemical structure. Artificial resins utilized in early stages were plastic, celluloid and melamine.

In 1920's, carbon fibers were introduced as the main reinforcement in composite materials used in aircraft industries and sports goods.

In 2000's composite materials are being widely utilized in automotive, consumer appliances, textile,

railways, defense, marine, building, electronic industries, etc.

1.3 CHARACTERISTICS OF COMPOSITES

Composite materials have excellent mechanical properties compared to other materials.

They have mechanical applications in aerospace, military and marine industries due to their fatigue strength and fatigue damage tolerances.

Composite materials are orthotropic in nature. Their Young's modulus and Poisson's ratio differ in all possible directions. They have high stiffness.

Composites have zero coefficients of thermal expansion, high vibration energy absorption and damping capacity.

Composites need less energy and pressure for their manufacture when compared to other materials.

➤ **Objects of Present Work**

- Study the different types of natural fibers the objectives are Hemp, Palm and Pineapple.
- To prepare composites by using natural fiber of desired size.
- To measuring the weights of fibers and the resin are studied.
- To fabricate the different weight and percentages with epoxy resin and hardener along with natural composites.
- To study the density of different natural fibers and strengths are checked.
- To study the different micro hardness of samples.
- To perform different type of tests for finds out different mechanical properties.
- To perform the tensile test on computer controlled machine and flexural tests on composite labs and impact tests on composite samples.

2.LITERATURE REVIEW

Many authors have already investigated composites with natural fibers as reinforcements in conjunction with polymer matrices. They have reported the superiority of hybrid composites. They planned complete diverse fabricating strategies of fiber composites and investigated the mechanical behavior and wear characteristics of those composites.

Bullent et al. (2006) tested the failure mode and cargo of fasteners in plain-woven Kevlar epoxy composite plates. In this methodology, technique relating to finite parts is developed for predicting injury initiation, progression and strength of joints. For failure analysis hashin, Hoffman and most stress is employed. The experiments were performed to work out the results of failure and to gauge the effect of joint analysis.

Ferreira et al. (2006) fabricated the composites of PVC and inexperienced coconut fibers using two techniques. The authors evaluated the degree of homogeneity of the mixer through dynamic modulus measurements. They concluded that that no physico-chemical interactions occur between the matrix and also the fibers.

Jorg Mussig et al. (2006) observed the micromechanical calculation models to find out the stiffness and impact resistance of a fiber strengthened epoxy-single-layer-composite. Cotton, ramie and manmade lyocell fibers were used in their work.

Paul et al. (2006) evaluated the bio-composites, the technology and their environmental recommendations. They studied the factors which are subjective to the performance of such natural fiber composites.

Wu and Cheng (2006) did experimental investigation of the result of Kevlar pulp reinforced with epoxy under dry and slippery conditions. Analysis was performed against stainless-steel on friction and wear tester. The experiments were conducted at the temperature range of 10-200°C, 50-60% ratio conditions. The relationship between the particular wear rate and also the friction constant against the Kevlar pulp content were found for each dry and water lubricated condition. Friction constant was reduced with increase in filler

content and optimum resolution was obtained once Kevlar pulp content was 60%. A reduction in the particular wear rate was seen once Kevlar pulp content had 40% volume of filler content due to the optimum resolution for the composites.

Bledzki et al. (2007) reinforced abaca fiber reinforced polypropene composites with totally different fiber loadings and flax and jute fiber reinforced polypropene composites with 30% weight. The mechanical properties and structural properties for these composites were investigated. They found tensile, flexural and Charpy impact strength for fiber loadings as upto 40% reduction.

Donghwan Cho et al. (2007) reinforced the composites with natural and thermosetting matrix using the compression molding technique by means of all cut natural fibers of concerning 10 mm long. They investigated the surface shear strength, flexural properties and dynamic mechanical properties of every green composite system. The authors concluded that the properties of the compound resins were considerably improved by incorporating the natural fibers into the resin matrix.

3. METHODOLOGY

Composite is composed of two main components: the fiber as reinforcement and the matrix. The reinforcing element is able to support high tensile loads although the matrix imparts rigidity to the composite. The application of stress on the composite is results transfer of the loads from one fiber to another, via the matrix. The stiffness of the matrix is often accompanied by brittleness. Nevertheless, the combination of fiber and matrix makes for a tough material. The composites may fail by one or two mechanisms plastic flow or brittle cracking. Based on existing experience and knowledge of synthetic fiber composites, the mechanical behavior of plant fiber composites has been extensively characterized and analyzed. The work has mainly addressed measurements of pure tensile properties, as well as bending and impact properties. A considerable amount of literature has been published on composites containing lignocellulosic fibers produced by the forest and paper industry such as cellulose, wood fiber and wood dust. Other studies have looked at agricultural fibers such as kenaf, pineapple, sisal, hemp, coir and rice husks.

Palm fiber

Oil palm (*Elaeis guineensis* Jacq.) is the highest yielding edible oil crop in the world. It is cultivated in 42 countries in 11 million ha worldwide. West Africa, South East Asian countries like Malaysia and Indonesia, Latin American countries and India are the major oil palm cultivating countries. The oil palm plantation annually produces about 55 ton of dry matter in the form of fibrous biomass while yielding 5.5 ton of oil. From oil palm tree, lignocellulosic fibers can be extracted from trunk, frond, fruit mesocarp and empty fruit bunch (EFB). Empty fruit bunch is the fibrous mass left behind after separating the fruits from sterilized (steam treatment at 294 kPa for 1 h) fresh fruit bunches (FFB). Among the various fiber sources in an oil palm tree, EFB has potential to yield up to 73% fibers and hence it is preferable in terms of availability and cost. Palm oil industry has to dispose about 1.1 ton of EFB per every ton of oil produced.

At first the researchers extracted long **textile fiber** from the byproducts of date palms, and then converted it into fiber tow, chopped fibers, yarn, non-woven mats, woven fabric etc. Date palm fibers can be easily mixed with other long fibers like sisal, flax or **abaca fiber**. It is also possible to make yarn by mixing it with hemp or jute. These fibers derived from date palms are not only durable but also economical in production and compatible with textile & composite processing. In particular, these fibers provide the necessary features for the manufacture of future lightweight cars, sports goods, construction plaster reinforcement, sacks for packaging, rope, yarn and other products.

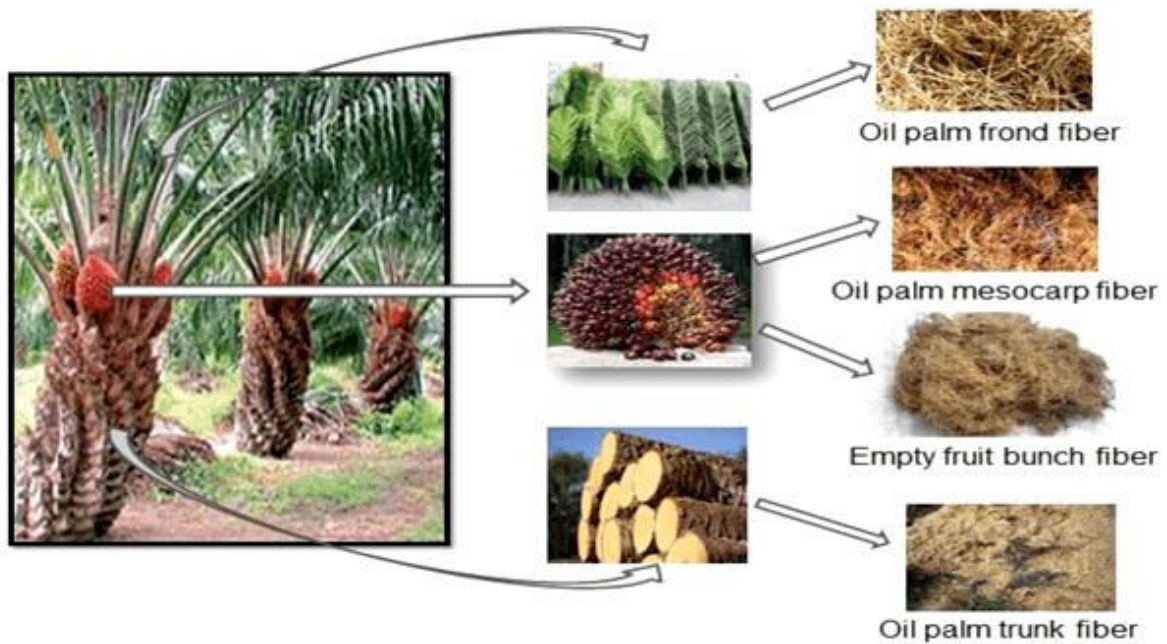


Figure Fehler! Kein Text mit angegebener Formatvorlage im

Dokument..2 – Palm Fiber Pineapple fiber

Every year tonnes of pineapple leaf fibers are being produced, though very small portions are being used in the field of feedstock and energy production. The expansion of biocomposites has amplified industrial usage that would release the possibilities to minimize the wastage of renewable materials. It promotes a non-food-based market for agricultural industry. It is white in colour, smooth, and glossy as silk, medium length fiber with high tensile strength. It has a softer surface than other natural fibers and it absorbs and maintains a good colour. Many health conscious people love to have Pineapple as their favorite dessert. It's because of many health benefits of the delicious fruit. It protects from a simple flu as well as fights off free radicals that cause cancer. It cleans the internal system to keep our body healthy through fibers that help in proper digestion. That's not all, it's not the only kind of fiber that a pineapple carries. Pineapple leaves are used to obtain Piña, a textile fiber that is used to make fabrics. Pineapple is mainly grown in sub-tropic countries

including Philippines, Taiwan, Brazil, Hawaii, India, Indonesia and the West Indies. Pineapple has been produced well amount in Bangladesh also. And the country has good potential in producing pineapple fiber and corresponding products.

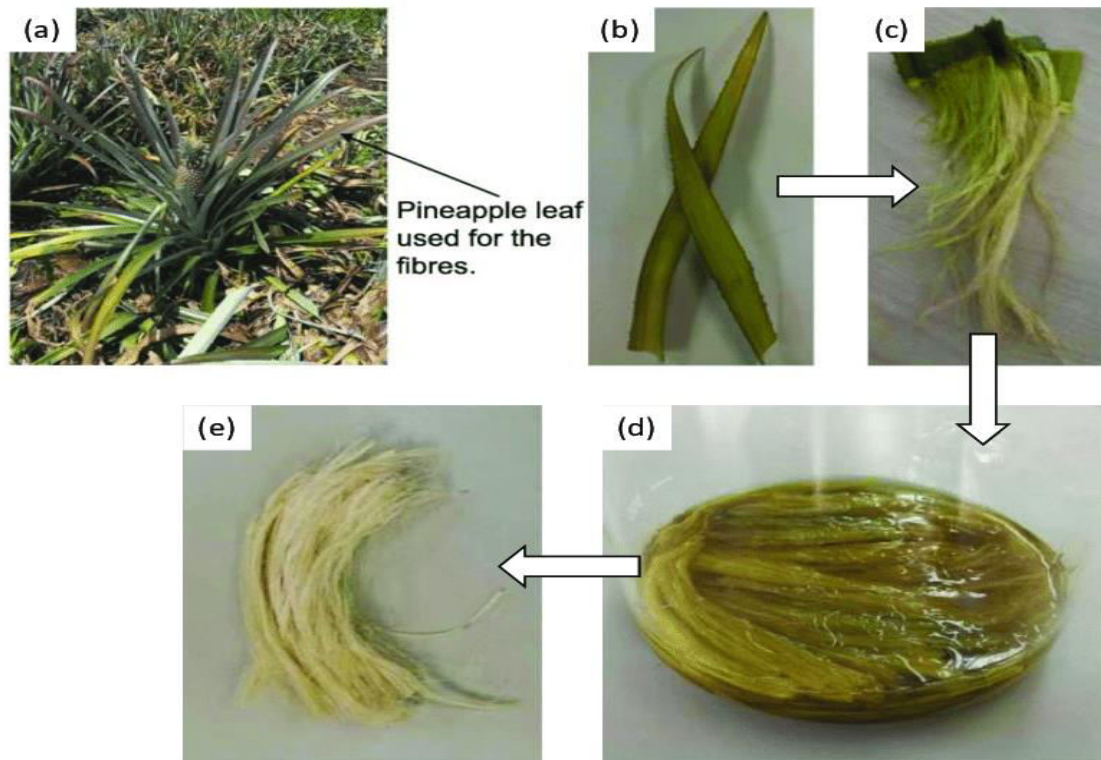


Figure 2 The pineapple plant and the leaves' fiber extraction: (a) pineapple plant at a farm in Malaysia, (b) pineapple leaves, (c) raw pineapple-leaf fiber, (d) the fibers treated within 1% sodium hydroxide solution, and (e) the treated fibers



Figure Fehler! Kein Text mit angegebener Formatvorlage im Dokument...3 – Pineapple Fiber
Properties of Resin

Anhydride- cured low-viscosity standard matrix system with extremely long pot life. The reactivity of the system is adjustable by variation of the accelerator content. The system is easy to process, has good FIBER impregnation properties and exhibits excellent mechanical, dynamic and thermal properties. It has an excellent chemical resistance especially to acids at temperatures up to 80 °C. This epoxy system fulfills MIL

specifications R 9300.



Figure Fehler! Kein Text mit angegebener Formatvorlage im Dokument..3 – epoxy resin

Properties of Hardener

Hardener (Hy 951) is a three components, low viscosity, unfilled epoxy casting resin system curing at room temperature, designed for potting or encapsulating low voltage and electronic components



Figure Fehler! Kein Text mit angegebener Formatvorlage im Dokument..4 – Hardener

Fiber Treatment

The fiber is soaked with 5% of NaOH for 8Hrs at 30deg/cel. The mixture took about 24 hours for complete dry. The specimen then were cut into standard dimension according to ISO standard fiber have improved significantly as compared to undertaken flax and sisal fiber especially at the optimum level of NaOH.

Fiber Treated Method:

1. First the fiber is to be washed with the distilled water.
2. Then take a beaker and put 50gms of NaOH for 1ltrs of distilled water.

3. Then pour the mixed solution (2ltrs) in the tray and soak the 4-natural fiber.
4. The fiber have been soaked for 2hrs.
5. Then washed with the distilled water.
6. Washed with tap water.
7. Then the natural fiber has been kept for drying in sun light for 4hrs.

Most polymers may be used, including all thermoplastics, some thermosets, and some elastomers. There are tens of thousands of different materials available for injection moulding. The available materials mixed with alloys or blends of previously developed materials means that product designers can choose from a vast selection of materials to find the one that has exactly the right properties.

Materials are chosen based on the strength and function required for the final part; but also each material has different parameters for moulding that must be considered. Common polymers like Epoxy and phenolic are examples of thermosetting plastics while nylon, polyethylene, and polystyrene are thermoplastic.

CONCLUSION

The present work focuses on the fabrication and characterization of natural fiber-reinforced epoxy composites using palm, pineapple, and hemp fibers. Natural fibers are promising reinforcement materials because of their low weight, availability, renewable nature, and potential to reduce dependence on synthetic fibers. Epoxy resin acts as the matrix material, binding the fibers together and transferring the applied loads throughout the composite structure. The natural fibers are treated with sodium hydroxide (NaOH) to remove surface impurities and improve fiber–matrix adhesion. The treated fibers are then combined with epoxy resin and hardener to fabricate composite specimens with different fiber weight percentages. The prepared specimens can be evaluated for density, microhardness, tensile strength, flexural strength, and impact resistance to understand their mechanical performance. The properties of the fabricated composites depend on several factors, including fiber type, fiber content, fiber treatment, fiber distribution, resin impregnation, and bonding between the fiber and matrix. A comparative study of palm, pineapple, and hemp fiber composites can help identify suitable reinforcement materials for lightweight and cost-effective engineering applications. Overall, natural fiber-reinforced epoxy composites have potential applications in automotive components, furniture, construction materials, and other non-structural engineering products. However, the selection of the most suitable composite should be based on experimentally measured mechanical properties and durability. The results obtained from this investigation can provide a basis for further research into sustainable composite materials.

References:

1. Dr. Mohamad Midani, Dr. Naheed Saba, Dr. Othman Y. Allothman, “Date Palm Fiber Composites”, Publisher: Springer Singapore.
2. AL-Oqla F M, Allothman O Y, Jawaaid M, Sapuan S M, and Es-Saheb M H 2014 Processing and properties of date palm fibers and its composites Biomass bioenergy 1-25
3. <https://textilevaluechain.in/2020/07/17/first-long-textile-fiber-from-date-palm-by-products-developed-by-researchers-in-egypt/>. Accessed date: 19/02/21
4. https://www.researchgate.net/publication/265085416_Processing_and_Properties_of_Date_Palm_Fibers_and_Its_Composites, Accessed date: 19/02/21
5. W Ghorri, N Saba, M Jawaaid and M Asim, “A review on date palm (Phoenix dactylifera) fibers and its polymer composites”, <https://textilelearner.net/date-palm-fiber-properties-chemical-treatments-applications/>
6. Marquis-Favre, C.; Premat, C.; Aubrée, D.; Vallet, M. Noise and Its Effects—A Review on Qualitative Aspects of Sound. Part I: Notions and Acoustic Ratings. *Acta Acust. United Acust.* 2005, 91, 613–625.
7. Marquis-Favre, C.; Premat, C.; Aubrée, D. Noise and Its Effects—A Review on Qualitative Aspects of Sound. Part II: Noise and Annoyance. *Acta. Acust. United Acust.* 2005, 91, 626–642.
8. Cao, L.; Fu, Q.; Si, Y.; Ding, B.; Yu, J. Porous materials for sound absorption. *Compos. Commun.* 2018, 10, 25–35.
9. Na, Y.; Jeff, L.; Johni, C.; Gilsoo, C. Sound Absorption Coefficients of Micro-Fiber Fabrics by Reverberation Room Method. *Text. Res. J.* 2007, 77, 330–335.
10. Yang, T.; Xiong, X.; Mishra, R.; Novák, J.; Militký, J. Acoustic evaluation of Struto nonwovens and their

relationship with thermal properties. Text. Res. J. 2018, 88, 426–437.

11. Papadopoulos, A.M. State of the art in thermal insulation materials and aims for future developments. Energy Build. 2005, 37, 77–86.
12. European Council Directive 67/548/EEC of 27 June 1967. On the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances. Off. J. Eur. Commun. 1967, 196, 1–98.