A Study of Short Areca Fiber Reinforced PF Composites

G. C. MOHAN KUMAR, *Member IAENG*

ABSTRACT
Mechanical properties of the fibers extracted from the areca are determined and compared with the other known natural fiber coir. Further these Areca fibers were chemically treated and the effect of this treatment on fiber strength is studied. Areca fiber composite laminates were prepared with randomly distributed fibers in Maize stalk fine fiber and Phenol Formaldehyde. Composite laminates were prepared with different proportions of phenol formaldehyde and fibers. Tensile test, moisture absorption test, and biodegradable tests on these laminates were carried out. Properties of these areca-reinforced phenol formaldehyde composite laminates were analyzed and reported.

1. INTRODUCTION

Manmade fibers using glass, carbon, boron etc. are being used as reinforcing materials in the fiber-reinforced plastics which have been widely accepted as materials for structural and nonstructural applications. The main reason for the interest in FRP is due to their specific modulus, high stiffness, and strength to weight ratio compared to other conventional materials. However, these materials are prohibitively expensive in their use for other general purposes and applications. Nowadays natural fibers like, cotton, coir, sisal jute and other natural fibers have attracted the attention of scientists and technologists for applications in packaging, low-cost housing, and other structures. It has been found that the natural fiber composites possess required mechanical strength and other properties with better electrical resistance, good thermal and acoustic insulating properties, and high resistance to shocks and fracture.

The increasing interest in introducing degradable, renewable, and inexpensive reinforcement materials which have been environment-friendly has stimulated the use of hard cellulose fibers. The low cost, less weight, and density make the natural fibers an attractive alternative. The current major uses of hard cellulose fibers like flax, jute, banana, sisal, are in textile, packaging, and paper manufacturing. These fibers are considered as hard cellulosic fibers because of their reasonably high tensile modulus and elongation at break.

Manuscript received February 6,2008. This work was supported by the Council of Scientific and Industrial Research, New Delhi, INDIA. Scheme: No.22(0408)/06/EMR-II Dated 11-10-2006.
Dr. G C Mohan kumar, Professor, Mechanical Engg. Dept. is with the National Institute of Technology Karnataka, Surathkal, Mangalore- 575 025, INDIA. Ph:+91-(0)824-2474000
Fax: +91-(0) 824-2474033 Mob:(0)9480065648
email: mkumargc@rediffmail.com

Many attempts were made by scientists and technologists to utilize natural fibers in the fabrication of composites [1, 2]. Their efforts to introduce the natural fibers composites are because of the following reasons.

1. These fibers, despite their low strength can lead to composites with specific strengths because of their low density.
2. Natural fibers are abundantly available renewable resources.
3. Dried Natural fibers are nontoxic and eco-friendly and biodegradable and are quite cheap.
4. Scientific data of the structure and properties of the fibers are readily available.

In this paper, the mechanical properties of the fibers extracted from areca fruit are determined and compared with the other known natural fiber. Further, these areca fibers were chemically treated to improve the mechanical properties using NaOH soaked in a known concentration of NaOH for different periods. Also the effect of this chemical treatment on maize fiber is studied. The composites were prepared with different proportions short areca fibers reinforced in maize stalk fine fibers and phenol formaldehyde. Variations in the static bending strength of these composites were analyzed. Other mechanical properties using adhesion strength, moisture absorption test, and biodegradable tests were carried out and results were reported.

2. NATURAL ARECA FIBERS

Among all the natural fiber-reinforcing materials, areca appears to be a promising material because it is inexpensive, availability is abundant and a very high potential perennial crop. It belongs to the species Areca catechu L., under the family palmecea and originated in the Malaya peninsular, East India. Major industrial cultivation is in East India and other countries in Asia. In India, areca nut cultivation is coming up on a large scale basis with a view to attaining self sufficiency in medicine, paint, chocolate, Gutka, etc. It is estimated that about 6 Lakh tonnes of areca husk is available in south West-India [3].

The husk of the Areca is a hard fibrous portion covering the endosperm. It constitutes 30–45% of the total volume of the fruit. Areca husk fibers are predominantly composed of hemicelluloses and not of cellulose. In Table 1 the chemical composition of Areca fibers is shown along with few known fibers. Areca fibers contain 13 to 24.6% of lignin, 35 to

64.8% of hemicelluloses, 4.4% of ash content and remaining 8 to 25% of water content. The fibers adjoining the inner layer are irregularly lignified group of cells called hard fibers and the portions of the middle layer contain soft fibers. Table 1 compares the chemical composition of Areca fiber with some other important natural fibers. Areca fiber is highly hemicellulosic and is much greater than that of any other fibers. Coir has a higher lignin content than fibers. And sisal fiber has higher cellulosic content compared to Banana, sisal, and other fibers. Lignin and hemicelluloses in maize stalk fibers are considerable to cellulose with areca fibers. Properties of natural fibers depend mainly on the nature of the plant, locality in which it has grown, age of the plant, and fiber extraction method used. Areca fibers are hard and show similarity to coir fibers in cellular structure.

The unmanaged green Areca husks left in the plantation lead to bad odors and other decay-related environmental problems. Therefore extensive planning for the disposal of this material is required. The present use of this highly hemicellulosic material is as a boiler fuel when sufficiently dried. However for the use of these fibers as a reinforcing material for composites, a study of the chemical and physical characteristics is required.

Table 1. Chemical composition of natural fibers.

Fiber	Lignin %	Cellulose %	Hemicellulose %
Areca	**13 – 24.6**	**--**	**35-64.8**
Maize stalk	**10-13**	**38- 42**	**21-23**
Coir	**40-45**	**32-43**	**0.15-0.25**
Sisal	**10-14**	**66-72**	**12**
Banana	**5**	**63–64**	**19**

Generally acids and alkalis have been used for modifying the properties of natural fibers like jute, coir etc. Strong alkali solutions lead to a reduction in strength and an increase in elongation does not cause significant lowering in strength. Coir fibers were subjected to alkali treatment for coir–polyster composites by Prasad et al. [4] and it was found that flexural strength, modulus, and impact strength of composites containing alkali-treated fibers were higher than those containing the same volume fractions of untreated fibers. Combined alkali treatment and irradiation of jute can also be achieved by treatment of the fibers with 2% sulfuric acid solution followed by alkali of mercerizing strength. A. K. Mohanty etal [5] studied the chemical surface modifications of jute fabrics involving bleaching, dewaxing, alkali treatment, cyanoethylation and vinyl grafting are made in view of their use as reinforcing agents in composites based on a biodegradable polyester amide matrix. The effect of different fibre surface treatments and fabric amounts on the performance of resulting composites are investigated. The mechanical properties of composites like tensile and bending strengths increase as a result of surface modification.

It has been reported earlier about the possibilities of using Areca fibers as a potential reinforcement in Phenol Formaldehyde or Urea Formaldehyde resin [2]. And the mechanical performance of phenol formaldehyde resin can be greatly improved by the incorporation of these fibers. G. Kalaprasad [6] studied the chemical surface modific- ations such as alkali, acetic anhydride, stearic acid, permanganate, maleic anhydride, silane and peroxides given to the sisal fibres. Fibers and matrix were found to be successful in improving the interfacial adhesion and compatibility between the fibre and matrix. The nature and extent of chemical modifications were analyzed by infrared spectroscopy while improvement in fibre- matrix adhesion was checked by studying the fractography of composite samples using a scanning electron microscope. Assessment of water retention values has been found to be a successful tool to characterize the surface of the stearic acid modified fibres. Many scientists have attempted to increase the tensile strength and surface characteristics of natural fibers in the preparation of natural fiber composites. In the present work, areca and maize stalk fibers were treated with alkali and their effects were studied and presented.

3. ARECA FIBERS

Selected variety of tender areca in a west –coast region was used to study the strength of fiber and to prepare the composites. Green husks of tender areca were soaked in water for about 4 days. The soaking process loosens the fibers and fibers can be extracted out easily. The Areca fibers were separated from the partial dried Areca husk using slow speed hammer mill. Completely dried and thrashed husks were forced through the cyclone separators repeatedly till the neat fibers were separated.

3.1. STRENGTH OF ARECA FIBERS

For any structural material the strength must be confirmed in order to satisfy the requirements of application. In nature, most of the natural fibers exhibit better tensile strength than flexural strength. Here, the tensile strength of Areca fiber is determined and compared with the other well-known natural coir fibers. Selected Areca husks were used to prepare the fibers as explained in the earlier section. The following section describes the brief procedure for determining the areca fiber tensile strength. Versatile tensile equipment controlled by the computer (Hounsfild, UK) is used to conduct the Areca fiber strength test. A personal computer controls the movement of the loading platform of the machine very accurately through a microprocessor-

interfaced device. A variable load of 0.1N to 50N with adjustable platform speed from 5 to 200 mm/ min. The relevant data, graph, and details can be stored or transferred to other software. Since the computer software works on a Windows environment, the results can be processed conveniently.

The dried Areca husk selected randomly among the stock is considered for the experimentation. Hard fibers are separated from the Areca husk as explained earlier. Separated Areca fiber was fixed in a paper support so that the Areca fiber should not be twisted or broken during fixing into the jaws. The size and shape of paper support was used as recommended in the procedure for testing the fibers. This helps in maintaining a required gauge length of the specimen also. The quick adhesive was used to fix the fiber in the fiber support. The gauge length of test specimen was maintained at 20 mm in all the experiments.

The specimen along with the paper support was fixed in the specially designed jaws of the machine. Then a wing of the paper support was cut off so that the force developed in the machine will be acting totally on the fiber specimen. The gauge length, limiting load, displacement, speed of moving platform in the direction of loading and return and other data required for the testing were assigned and stored. The fiber was loaded gradually and was observed till the end of break. The experimental data were recorded for further analysis. In order to compare the results of Areca, similar tensile tests were carried out for natural coir also. A seasoned coconut was taken and coir were removed and dried for about 5 days and tested in the same testing conditions of Areca.

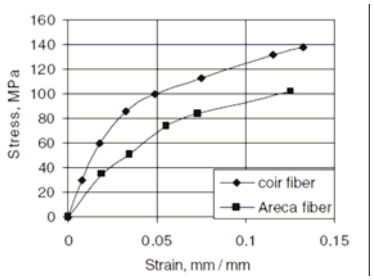

Fig. 1 Stress-strain diagram of areca & coir fiber.

The diameters of the areca fibers vary from 0.3188 to 0.465 mm. About 150 samples were carried out and average values of the properties are reported. Tensile strength, Young's modulus, and elongation at break were evaluated. Figure 1 shows the stress-strain diagram of areca & coir fiber. The results shows that the ultimate stress is around 85–101.85 MPa with 11–12.5% elongation at break. The curve of this stress–strain diagram for the areca fibers is identical and the nature of fracture exhibit like a ductile fracture. The Scanning electron microscope picture of the fracture surface is shown in the figure 2. The fracture surface is a plain and fracture of most of the micro vascular tubules has occurred at a time. It appears like a honey comb structure with micro vascular tubules. The Young's modulus varies in the range of 1100–1240MPa. Whereas the tensile experiment conducted on coir shows that the ultimate stress is around 110–138 MPa with 11.5–13.25% elongation at break. The Young's modulus for the coir is 2560–3620 MPa for the region up to the approximate linearity on graph. The ultimate strength and Areca elongation at break of Areca fiber is slightly lesser than the coir fiber.

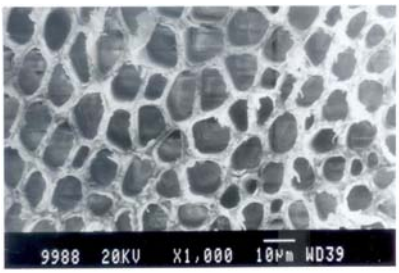

Fig. 3 SEM image of fracture surface of areca fiber

3.2 Alkali Treatment of Areca Fibers

Early literatures on natural fibers [5]–[7] indicate that many fibers when they are treated chemically, the mechanical and other properties will alter. The following sections explain the chemical treatment of Areca fiber and their effect on mechanical strength aspects. Effect of chemical treatment with sodium hydroxide NaOH of Areca fiber on mechanical properties was studied. Fibers were soaked in 5, 10, 15, 20, and 25% NaOH solution for about 12, 24, 36, 48, and 60 hours. These fibers were further washed with water containing few drops of acidic acid. Finally, the fibers were washed again with water and dried. This treatment leads to the irreversible mercerization effect, which increases the amount of amorphous hemicellulose at the expense of crystalline cellulose. Mercerization treatment improves the fiber surface adhesive characteristics by removing natural and artificial impurities, however SEM images of treated fibers shows that no significant changes in the surface topography. The treatment results in clean fiber surface. The study reveals that weight of the Areca fiber was decreased by 8-13% after alkaline treatment.

Further, Areca fiber specimen was tested for tensile strength of natural fibers. The ratio of the strength of chemically treated Areca fiber to natural Areca fiber was calculated. Chemical treatment of natural fiber with NaOH shows that the treatment favorably increases the strength of the fibers. This is because as the crystalline cellulose dissolves, lignin increases in the Areca fiber. Once the Areca fiber is soaked in the alkaline bath, the material considerably shrinks during drying. (More than 18.52% shrink was observed across the diameter). In Figure 3, the stress–strain characteristic of natural and treated Areca fibers (with 15% concentration and 48 h soaking time) is shown. The differences in

stress–strain behavior of untreated and treated fibers are evident from this figure.

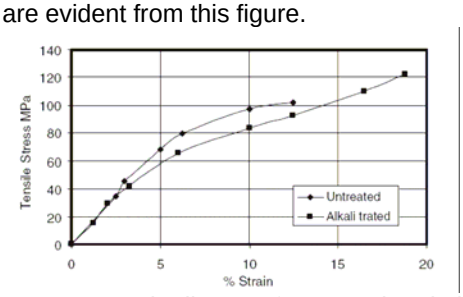

Fig. 3. Stress–strain diagram for natural and alkali-treated Areca fiber.

Fiber modification by alkali treatment improves the overall mechanical performance of the fiber. Alkali treated Areca fiber exhibits higher tensile strength than the natural fiber. Maximum stress at fracture is 101.85MPa for natural fibers and 123.36MPa for alkali treated fibers. Considerable increase in stress is observed in this treatment. Figure 4 shows the variation of tensile strength ratio of NaOH treated to natural Areca fiber. Lesser the percentage of NaOH concentration, it requires more soaking time to improve the strength. The maximum ratio of tensile strength ratio of NaOH treated Areca fibers to natural Areca fibers occurs when the soaking time is 25–55 h for 10–20% of NaOH concentration. With more soaking time, the ratio of strength decreases due to the biodegradation of Areca fiber hemicelluloses. This is the case if the percentage of NaOH concentration is 25% or more. The optimum soaking time for about 15% NaOH concentration is 28–32 h which gives the better strength about 123.36 MPa. The disadvantage of Areca fiber soaked with NaOH is that it becomes highly flexible. However the proper soaking time with required percentage of NaOH solution makes the areca fiber usable in the preparation of composites.

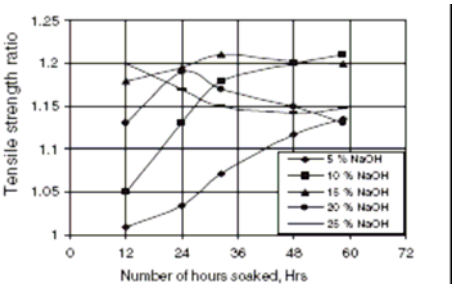

Fig. 4. Variation of tensile strength ratio with soaking time.

4. MAIZE FIBERS

Seasoned and sun dried maize stalks were collected from the field. The lower third part of stalk was used to prepare short fibers. To determine the strength of maize fiber, fibers of size about 1.5x0.5mm uniform sectioned were extracted. These fibers then tested in the machine as explained in the earlier section. The ultimate strength of the fiber is 152MPa with average Young's modulus of 8582MPa. Fig.5 shows the stress–strain diagram for natural Maize fiber. The strength of the fiber increases with strain till it reaches its ultimate value and then gradually decreases before break as shown in the figure. The SEM image of the fracture surface shows the fracture of micro vascular tubules partly by shearing in the later stages.

4.1 Alkali Treatment of Maize Fibers

Effect of chemical treatment with sodium hydroxide NaOH of Maize fiber on mechanical properties and surface texture were studied. The stress–strain behavior of treated fibers for different concentration and time as discussed in the earlier section for the areca fiber reveals that there is no considerable change in the strength. The SEM images of the maize fiber surface are shown in Figure 7(a-d). These pictures shows the successive stages of the fiber soaked in NaOH for 12, 24, 36hours. It is evident from these figures that clear fibers are obtained by dissolving some crystalline celluloses, waxes etc. over the surface. Fiber modification by alkali treatment improves the surface properties considerably in maize fibers.

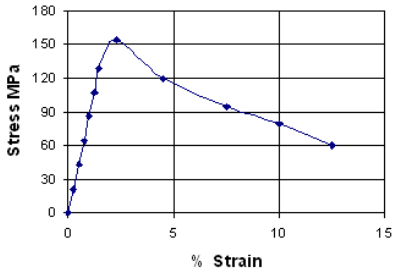

Fig.5 Stress–strain diagram for natural Maize fiber.

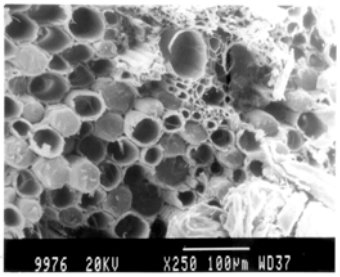

Figure 6 SEM image of fracture surface of Maize fiber

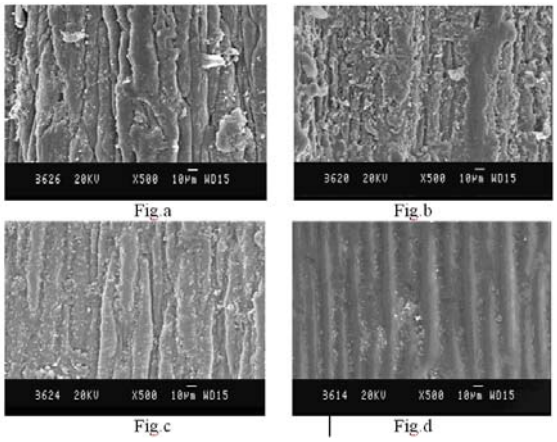

Fig.7. SEM images of fiber surface: a) Natural, b) treated for 12hours, c) 24hours and d) 36hours.

5 ARECA FIBER- REINFORCED PF COMPOSITES

Areca fiber-reinforced Phenol Formaldehyde composites were prepared by following the standard method for the preparation of wood based particle boards. Different composite plates were prepared with 1000gm of Areca fiber, 140gm of maize stalk short fiber [7] with 100, 200, 300, 400, 500gm of phenol formaldehyde. A composite plate is designated as PF100 for plate prepared with 100 gm of PF and similarly for other plates. Thoroughly mixed Areca fibers, Maize fibers and resin were pressed in a hydraulic hot press at a temperature of 140 C and a pressure of 2 MPa for 16 min.

5.1 Tensile Test

According to IS: 2380 (Part v)-1977 the tensile strength of the composite in the direction normal to the surface was determined. A square specimen of 50mm side and thickness as that of prepared plate is considered for the test. Loading fixtures made of Aluminum 50mm square are glued to the composite using suitable adhesive. The specimen was loaded in the Hounsfield universal testing machine and loaded gradually until the failure of the specimen occurs. Figure 8 shows the Load – deflection curves for the various areca-reinforced PF composite plates. The tensile stress-strain strength of composite plate increases in % PF in composite up to 400 gm and later decreases with increase in PF. The maximum tensile stress of Areca- reinforced PF composite plate specimen PF 400. Maximum tensile load is 0.2488 MPa for PF 400 composite plate.

5.2 Static Bending Strength

According to IS: 2380 (Part iv)-1977 the composite specimen was prepared for static bending. Each test specimen with 50 mm width, length 240 mm, and thickness 10 mm were prepared. The span (center to center distance between roller supports) for each specimen is 150 mm. The specimen is loaded at the center of the span in the universal testing machine. The test is carried until the specimen completely fails.

Fig. 9 shows the load–deflection curve of static bending strength of Areca-reinforced PF composites. This figure shows that the bending load for the composites increases with increase in Phenol formaldehyde. The composite PF 500 has taken the maximum bending load compared to other composite. The maximum static bending load of Areca-reinforced PF composite plate is 223.6 N. The corresponding flexural strength during break for this specimen is 10.01MPa. The minimum static bending load of 81N is recorded for PF100 composite and the flexural strength during break for this specimen is 5.4MPa.

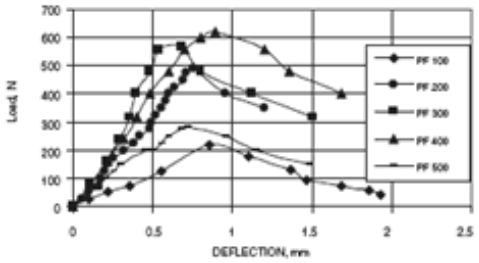

Fig.8 Load–deflection curves for areca PF composites

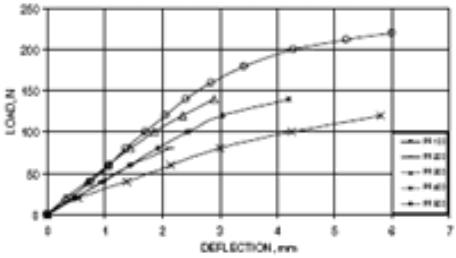

Figure 9.Load–deflection curve for areca- PF composites.

6. MOISTURE ABSORPTION TEST

Most natural fibers absorb more moisture compared to synthetic fibers. Water is predominantly absorbed at the fiber interface and matrix. The specimens were prepared from a 10-mm thickness plate with size 50 mm wide and 75 mm long. The specimens were immersed in water for a period of 7–15 days. The moisture content in the composite is measured by the weight gain of the material in regular intervals. The percentage moisture content is expressed as the ratio of increase in weight to the weight of dry specimen.

Fig.10 shows that the amount of moisture in the composite increases with time and later it becomes constant. It absorbs about 6–7.2% of its weight. Compared to conventional wood-based particle board it is very small where as the moisture (water) absorption for commercial wood-based particle board is more than 30-40%. Therefore this experiment shows that the composite made of areca fibers have significantly less moisture absorption.

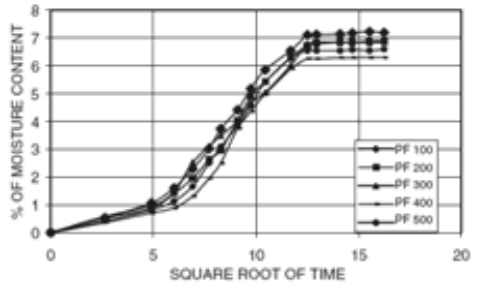

Fig. 10 Moisture absorption in PF composites.

7. BIODEGRADABLE TEST

Biodegradation of a substance is the process in which microorganisms use the substance as food source. The degradation involves bond scission reactions in the backbone of polymers, so that the original form disappears. Appropriate conditions in terms of temperature, pressure, and nutrients concentrations have to be maintained for optimization of rate of biodegradation. Usually, biodegradation products are not toxic or environmentally harmful.

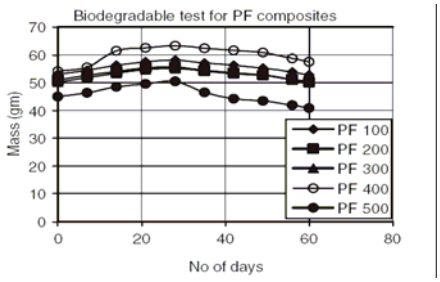

Fig. 11. Biodegradable test result for Areca PF composites.

According to IS standard, the specimen of 50-mm wide and 75-mm long were kept in compost for a period of 2–3 month with pH maintained and observing the changes in the weight of the specimen. In this experiment, the specimen is kept in compost for a period of 60 days. It has been observed that at the initial stages the specimens show an increase in weight for nearly one month and then start loosing weight, showing the biodegradability. It is a very slow process since the Areca fibers do not decompose at faster rate. Fig.11 shows that the PF composites absorb some amount of moisture present in the compost in the early stages and there is an increase in their weight for some period of time. After this, there is a decrease in the weight because of reaction between the enzymes secreted by the organism and the polymer chains or additives, which make up the compound.

8. CONCLUSION

The strength of natural Areca fibers were determined and found to be 101.85 MPa. Chemical modifications of fibers by alkali treatment were carried out to study the strength effect of Biodegradable test for PF composites these fibers. The EMS image of the fracture surface is plain and fracture of most of the micro vascular tubules has occurred at a time and show the brittle behavior . Alkali treated Areca fibers show a maximum tensile strength of 123.36 MPa and is more than the strength of natural fiber. Strength of maize fiber higher than areca fiber and is 152MPa. The alkaline treatment of the maize fibers improves the fiber surface favorably as discussed in section.

The Areca reinforced phenol formaldehyde composites of thickness 10 mm were prepared. These composite are found to have good tensile strength in the direction normal to the surface and the maximum tensile stress for the composite PF400 observed is 0.249MPa. The static bending test shows that, for PF200 composite the maximum stress is 10.01MPa. The areca composite exhibits an excellent resistance to moisture absorption and is about 6–7% and very low compared to wood-based particle boards. The biodegradability of Areca fibers is very slow and hence better and longer life of composite. The PF composites absorb some amount of moisture in the early stages and biodegradation happens at slower rate. The test results of areca-reinforced PF composites indicate that this would be a very promising material with moderate life for packing other general structural applications.

REFERENCES

[1]. G.C.Mohankumar, Natural Areca Fibers and their Composites, Workshop on Natural Fiber Composites, Indian Institute of Technology Madras, Chennai, India, 2002
[2]. R.P.Swamy, G.C.Mohankumar, etal. Study of areca reinforced Phenol Formaldehyde Composites, Journal of reinforced plastics and composites, Vol.23, No. 13, 2004.
[3]. Areca, Publication of Central Plantation Crops Research Institute, Kasargod, India, 2007
[4]. Prasad, S.V., Pavithran, C. and Rohatgi, P.K. Alkali Treatment of Coir Fibres for Coir-Polyester Composites, J. Mat. Sci., 18: 1443-1454, 1983
[5]. A. K. Mohanty, M. A. Khan and G. Hinrichsen Influence of chemical surface modification on the properties of biodegradable jute fabrics polyester amide composites, Composites Part A: Applied Science & Manuf., Volume 31, Issue 2, Pg 143-150, February 2000.
[6]. G Kalaprasad, Bejoy Francis, Selvin Thomas, etal. Effect of fibre length and chemical modifications on the tensile properties of intimately mixed short sisal/glass hybrid fibre reinforced low density polyethylene composites Polymer International, vol.53, No.11, Pages 1624 – 1638
[7]. G. Manovendra, G.C.Mohankumar and S. Kumarapaa, Study of Mechanical properties of areca and glass fibers reinforced phenol formaldehyde composite, International Conference on Frontiers in Design & Manufacturing Engineering, Karunya University, Coimbatore, Feb. 2008.
[8]. Indian Standard, IS:2380 (Part: 1 toxxi) -1977, Methods of test for wood particle boards and boards from other lignocellulosic materials, Bureau of Indian Standards, New Delhi, India.