Low Cost Polymer Composites with Rural Resources

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ABSTRACT: The natural fiber composites can be very cost-effective materials, especially for the building and construction industry (e.g., panels, false ceilings, partition boards, etc.), packaging, automobile, and storage devices, etc. They can also be a potential candidate for partial replacement of high cost glass/Kevlar fibers to make polymer composites used for low cost applications. From the point of view of wood substitution, natural fiber composite boards could offer an excellent eco-friendly solution, considering ever-depleting forest reserves and corresponding premiums on wood. Composites based on locally available resources are poised to penetrate the market. Any value-added application avenues for these fiber composites would directly contribute to the economic benefit of their growers. With increasing emphasis on fuel efficiency, natural fiber-based composites are finding wider application in the transport industries. Hence, the value-added application of natural fiber-based composites made from rural industries will ensure the international market has cheaper substitution materials.

Keeping the above in view, this research work has been undertaken to process polymer composites using naturally available resources such as bamboo strips, coconut leaf sticks, etc. The strength property relationships of these composites are evaluated, after subjection to different environments. This study will enable the manufacturer to select these materials for suitable applications.

KEY WORDS: polymer, coconut, bamboo.

INTRODUCTION

WITH RAPID INDUSTRIALIZATION and changes in the life style of people, new job opportunities and utilization of local resources in the rural sector are required. India, endowed with an abundant availability of natural fiber such as jute, coir, sisal, pineapple, ramie, bamboo, banana, etc., has focussed on the development of natural fiber composites primarily to explore value-added application avenues. Such natural fiber composites are well suited as wood substitutes in the housing and construction sector [1–3]. The development of natural fiber composites in India is based on the two-pronged strategy of preventing depletion of forest resources and ensuring good economic returns on the cultivation of natural fibers.

The developments in composite materials after meeting the challenges of the aerospace sector have cascaded down to cater for domestic and industrial applications and have come a long way in replacing conventional materials such as metals, wood, etc.,

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Material scientists all over the world have focussed their attention on natural composites reinforced with jute, sisal, coir, pineapple, etc. primarily to reduce the cost of raw materials. The natural fiber composites can be very cost-effective materials, especially for the building and construction industry (panels, false ceilings, partition boards, etc.), packaging, automobile and railway coach interiors, and storage devices. From the point of view of wood substitution, natural fiber composite boards could offer an excellent eco-friendly solution. With ever-depleting forest reserves and corresponding premiums on wood, a composite based on renewable resources such as jute, coir, sisal, etc. is poised to penetrate the market. Any value-added application avenues for these fibers would directly contribute to the economic benefits of their growers. With increasing emphasis on fuel efficiency, natural fibers such as jute-based composites are enjoying wider applications in automobiles, railway coaches and buses for public transport systems.

Satyanarayana [1] has worked on the incorporation of the natural fibers in polymer matrix and characterization of their new composites, with and without subject on to environmental conditions. A comparative study between the moisture absorption behavior of sisal and jute fiber composites in an epoxy matrix by Giridhar and Rao [4] reveals that sisal fiber, in spite of possessing a more compact structure than jute fiber, exhibits higher moisture absorption level in the composite form. A similar study on raw jute fiber in polyester resin matrix has also been reported by Roe and Ansell [3]. Simonsen [5] found that composites of wood or other bio-fillers in thermoplastics are not impervious to the effects of outdoor exposure. Degradation was noted, especially in stiffness. English and Falk [6] found that wood fiber/plastic composites absorb very little water. They also found that increasing fiber content substantially decreased the linear coefficient of thermal expansion. Coomarasamy and Boyd [7] examined the effect of freeze–thaw cycles on the mechanical properties of plastic lumber and found that at the end of the temperature cycle, none of the samples showed any signs of cracking, spilling, or other forms of deterioration, but several samples showed a reduction in strength. Mitra et al. [8] improved the fiber matrix bonding by treating the surface of jute fibers with pre-condensates such as phenol formaldehyde, melamine formaldehyde, and cashew nut shell formaldehyde before impregnating with the resin for composite fabrication. Their results indicate improvements in the mechanical properties of the composite made with treated fibers. Das et al. [9,10] have attempted to improve the mechanical performance of jute composites by using unidirectional oriented jute fiber as the reinforcement and general purpose polyester resin as the matrix.

Visualizing the increased rate of utilization of natural fiber in fabricating polymer composite, the present piece of work is carried out to (i) utilize the rural raw materials (viz. bamboo strips and fiber of the coconut leaf) to process the composite and (ii) evaluate its mechanical properties and environmental performance.

EXPERIMENTAL METHODS

To prepare the composite, epoxy resin with hardener (Araldite-LY556) was used as the matrix material. The bamboo strips/coconut fiber were spread horizontally layer-wise. Three-layered reinforced composite block of size ($300 \times 150 \times 8$ mm) was cast. Samples of dimension approximately ($90 \times 10 \times 7$ mm) were cut in parallel direction of alignment of the fiber/strips. These samples were subjected to various treatments and treated in alkaline (NaOH), acidic (NaCl), steam and sub-zero solutions/environments for various time periods. Treatments were so chosen to evaluate the viability of the use of these composites for various applications, viz. starting from space craft (sub-zero) to acidic and alkaline environments (marine use). The physico-mechanical properties were measured after different time intervals of treatments. A three-point bend test was carried out in a (INSTRON-1195) Universal Testing Machine and the flexural strength was calculated.

RESULTS AND DISCUSSION

After exposing the composite samples at different environments for different time periods, the amount of moisture absorbed was estimated (from the change in weight and volume) of the samples, shown in Figure 1, and the flexural strength was plotted in Figure 2 for composites made with bamboo strips.

From Figure 2 it is found that the bamboo-based composite absorbs a maximum amount of (about 18%) moisture in a steamy environment. The amount and rate of weight gain (moisture absorption) is slower/less when the samples are dipped in 5% NaOH and 10% NaCl solutions than when the samples are exposed to steam (95% RH at 50°C). At the initial period, i.e., on the first week of exposure, the rate of moisture absorption was rapid. After the samples were used for a prolonged time, the moisture absorption became stabilized. At sub-zero condition, the weight gain is less than that of the all other treatment conditions.

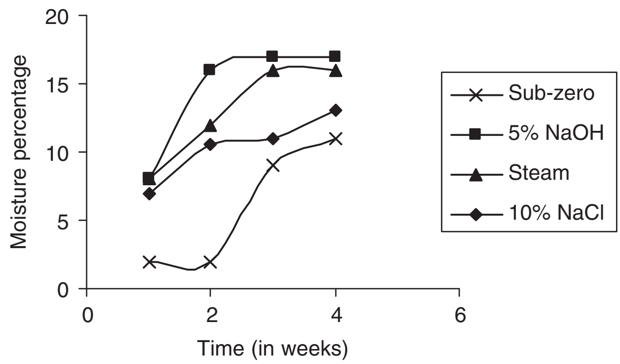

Figure 1. *Variation of moisture percentage with time.*

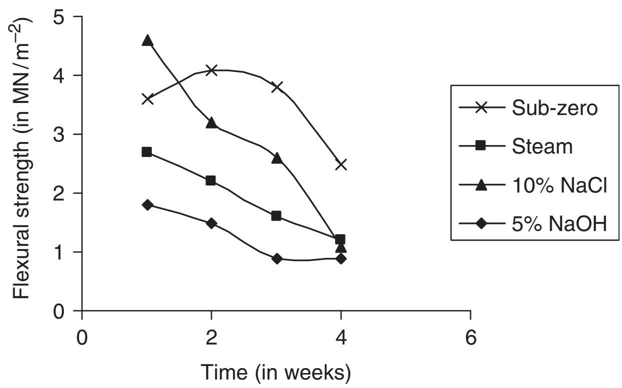

Figure 2. *Variation of flexural strength with time.*

The flexural strength of the composite for various treatments (Figure 2) reveals that after one week of treatment (except sub-zero treatment) all exposures exhibit a decrease in flexural strength. However, after one week of treatment the curves show a steady decrease in flexural strength until the end of the fourth week.

In the present investigation the effect of various environments on the bamboo plate-reinforced epoxy composites confirmed a degradation of composite properties (in general for all environments) when treated for a longer deviation. In the case of sub-zero conditions this composite exhibited slight increase in strength up to 2 weeks of exposure, which may have been caused by shrinkage/hardening of polymer matrix, and may be due to less moisture remaining in the composite, which improved the strength due to seasoning of bamboo strips.

The variation of weight gain with the coconut fiber-reinforced composite at different conditions is shown in Figure 3, and that of flexural strength for the treated samples is shown in Figure 4.

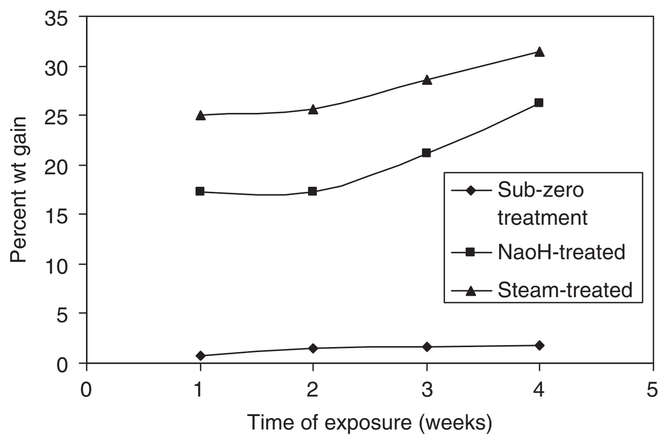

Figure 3. *Moisture absorption by coconut fiber composite.*

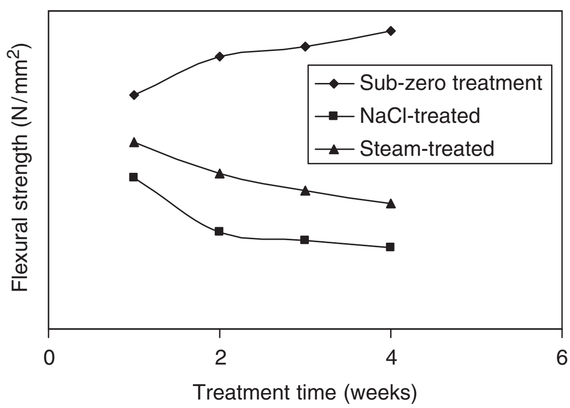

Figure 4. *Variation of flexural strength after various treatments.*

Figure 5. *Fracture surface of a typical specimen after sub-zero treatment.*

From the above figures it can be visualized that the coconut fiber-reinforced composite absorbs the maximum amount of moisture in steam (boiling water) treatment and the least in the sub-zero environment.

A sample with 5% NaOH solution had a maximum load-bearing capacity of $28.4\,N\,mm^2$ after treatment. The sample at sub-zero treatment sustained a maximum load of $56.2\,N\,mm^2$ after treatment. A sample showed a maximum flexural strength of $35.2\,N\,mm^2$ with steam treatment, compared to the sample (without treatment) which shows a maximum load carrying capacity of $58.32\,N\,mm^2$. From the above study it is observed that the composite shows least detoriation of flexural strength for the sample exposed to sub-zero environment.

From the above observations, it is found that the strength of the composites deteriorate at a longer exposure to steam alkaline mediums and that the strength is least affected at sub-zero environment. This implies that this composite is suitable for manufacturing the components that are operated/used at low temperatures.

A typical fracture surface of a coconut fiber-reinforced composite is shown in Figure 5, for a sample used at sub-zero treatment for four weeks. The breaking/pullout of the fibrils of the fiber is clearly visible. This is the evidence to justify that the load transfer takes place from the matrix to the fiber. This indicates that the fiber–polymer matrix interface bonding is good where the inter-lamellar shearing of fibrils have occurred.

CONCLUSIONS

The moisture absorption and absorption of salt (possibly) affected the changes which become stable after certain times of exposure to a particular environment. The bamboo fiber/epoxy composite used in this study bears a maximum flexural strength of $9.97\,MN\,m^{-2}$ and $58.32\,N\,mm^2$ for coconut leaf sticks. The amount of moisture absorption is more in case of the composite made with coconut leaf stick reinforcement. The mechanical properties of the composites exposed to steam, sub-zero, NaCl, and NaOH environments detoriate with prolonged exposure. The rate of reduction of strength was greater in an alkaline medium and increased rapidly with longer exposure time.

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