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Experimental Study of The Mechanical Properties of Banana Fiber and Groundnut Shell Ash Reinforced Epoxy Hybrid Composite

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ABSTRACT

Effect of addition of filler material to the natural fiber composite was experimentally investigated. Composites are manufactured by the conventional hand-layup method. All composites are made with a fixed banana fiber with 15% weight fraction addition of different weight fraction of (0, 3, 5, 7.5%) groundnut shell ash is added to the composite. Tensile, hardness, impact and compressive strength are conducted to find the mechanical behaviour of the composites. Preparation and testing were conducted according to ASTM standards. Results illustrate that mechanical properties are improved by the addition of groundnut shell ash to the epoxy based banana fiber composite. Natural fiber composites are predominantly used in automobile (Door pannels, interior parts and cabin linings), aerospace and packing material. Natural fibers have more advantages like low cost, biodegradable and low density than the inorganic materials, the environmental impact of the natural fibers are less compared to synthetic fibers.

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1. INTRODUCTION

Since 1900, Natural fibers are emerged as the reinforced material for the composites. Right now, natural fiber composites (NFC's) are used in the numerous applications which are the replacement for the particular synthetic fiber composites because of its advantages like low cost, biodegradable and low density. Natural fibers are bio and renewable material [1]. Plant, animal and mineral are the types of natural fibers based on its origin. Mineral fibers avoided in many countries due to causing health issues to humans [2]. Plant fibers cellulosed based fibers, cellulose is the major content in this fibers. Plant fibers are obtained from the parts of the plant which are stem, leaves, bast, seeds and fruits etc. Banana, jute, kenaf, flax, palm is the example for the plant fibers. animal fibers are protein based fibers, they are obtained from wool or hair of the animal. Alpaca, silk is the example for the animal fibers [3]. Plant fibers have the better mechanical behaviour than the animal fibers except silk fiber. Silk fiber has higher strength but cost of the fibers is more compared to the other fibers [2]. Banana is the most abundantly available in the earth. Banana fiber encompasses of 62-64 percentage of cellulose, 19 percentage of hemicellulose and 5 percentage of lignin are the significant components. Plant fibers that are fitted with the higher cellulose content possessing higher mechanical performance [3].

In PMC's agglutination between the polymer and fiber is the very important factor for procurement healthier mechanical performance. At the compound of the composite shear stress is transferred to the fibers by the matrix. With the higher agglutination higher performance are achieved, the life time of the material also convalesces. Mechanical properties not only depend on the fiber-matrix interaction they will depend on the matrix and fiber [4-11]. Size, growth time, orientation of fibers and alignment of the fibers are also affecting the performance of a material. At different locations, properties of fiber are different. Soil type, harvesting time and growth conditions are influences the chemical composition of the plants. These parameters depend on location, by the parameters cellulose content of the plant fiber differs. Cellulose content is the major influencing factor for enhance the better mechanical properties, with higher cellulose results in better mechanical properties. Banana fiber is available in almost 135 countries. In India, poovan cultivars are cultivated these fiber have the

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better cellulose content, so in this paper these fibers are used. Due to this change in properties same procedure of making NFC's does not gives the same mechanical properties [12-15].

Cellulose based fibers have some disadvantages which influences the mechanical behaviour. The main disadvantages of natural fibers are tends to attract the moisture from the environment results change in dimension of the composite. Hydrophilic nature of the fiber effect the fiber matrix interaction. Mechanical behaviour of the fiber composite can enhanced by treating the fiber either chemically or physically. Corona and ultra-sonic treatment are the major physical treatments to treat the NF's. Chemical treatment improves the agglutination between the polymer and fiber. When fibers were treated with alkalis, fibers are getting rough and porous were happen on surface of the fiber helps to better agglutination between the polymer and fiber. When fibers are treated with silane and hydroxyl groups are reducing the moisture content present in the fiber; results in better mechanical performance [16-28].

NFC's performance may be enhanced by hybridisation by addition of the fillers or fibers. Adding the filler material mechanical behaviour of the composite were improved. Addition of filler material helps to improve the agglutination between the polymer and fiber. Rate of water absorption also reduces by adding the filler material to the composites [29-37]. In this paper, we performed tensile, compressive, hardness and impact strength on banana/epoxy filled with groundnut shell ash composites manufactured with bidirectional alignment. The main purpose of this paper is comparing the mechanical performance of the composite with hybrid composite.

2. EXPERIMENTAL

2. 1. Materials Epoxy resin (LY556) and hardener (HY951) were purchased from CIBA GUGYE India Limited. Groundnut shell ash is obtained from the shell of the groundnuts. Groundnut shells were kept in electrical furnace at 1400°C for half an hour. Groundnut shells are burned completely and converted into ash. Then this ash is dried in an oven at 250°C for 3hours. Long banana fibers were obtained from the sri Lakshmi group of industries, Guntur, India. Banana fiber is shown in the Figure 1.

2. 2. Alkali Treatment NaOH is used to treat the banana fibers. Banana fibers were soaked in the 1% solution of NaOH for half an hour. Then these fibers are cleaned with the distilled water and kept in an oven at 50°C up to 45 minutes till the skiving of the moisture. Alkali treatment removes the elements of the fiber include hemicellulose, lignin.

It also modifies the structure of the cellulose. Chemical treatment with alkalis results increases the surface roughness of the NF's this improves the agglutination between the polymer and fiber. Treatment of NF's are shown in Figure 2.

2. 3. Composite Preparation Banana fibers are woven in mat form dimension of 250×250×1.5 mm^3. Woven fibers are oriented in bidirectional (0° and 90°). Epoxy is mixed with hardener in the ratio of 10:1 ratio. Groundnut shell ash is mixed with the epoxy resin while mixing forming of air bubbles are prevented. Composite are prepared by conventional hand-lay-up method. Four composites of fixed 15 wt% of banana mats with different groundnut shell ash weight fraction of (0, 3, 5 and 7.5 wt%) are prepared. The test samples were prepared as per ASTM standards. Specimens are shown in Figure 3.

Figure 1. A) Raw banana fiber, B) Woven banana fiber mat

Figure 2. Alkali treatment of fibers

Figure 3. Specimens after preparation of composites

2. 4. Standard Test Methods Used To obtain the mechanical properties, tensile, compression, Rockwell hardness and impact tests are conducted. Tensile test is conducted on universal testing machine INSTRON H10KS at spindle speed of 0.5 mm/min as per ASTM D 3039 with dimension of 250 x 25 x 3 mm. Impact strength, Izod test was conducted as per standards of ASTM D 256 with dimension of 64 x 12.7 x 3.2 mm. Compression test was conducted according to ASTM D 695 standards with dimension of 50 x 10 x 4mm. Hardness test was conducted on saroj hardness testing machine. The ¼ inch diamond ball indenter is forced into the specimens under a load of 60 kg_f. Rockwell hardness L-scale was used for finding the Rockwell hardness number. Rockwell hardness number is calculated by Equation (1).

$$H_R = N - \frac{d}{s} \quad (1)$$

Where, d = Depth, N and s are scale factors (N= 100, S= 0.002mm).

3. RESULTS AND DISCUSSION

Test results are tabulated in Table 1. Change in the tensile strength of the NFC's were shown in Figure 4. It is observed that banana fiber reinforced with epoxy composite attains the strength of 10.21 MPa. This epoxy based banana fiber composite filled with 3% wt. of groundnut shell ash attains the tensile strength of 12.02 MPa. It is shown that the filler content is help to improve the strength of the composite. Further increase in the filler material tensile strength of the NFC is decreases, also observed that filler content with 5 wt%; also gives the best values compared to the unfilled composite. When 7.5 wt% of ash filled composite, gives the lower value amid the other composites.

Results exhibits that agglutination between the fiber and polymer material augment with addition of the filler material. The interaction between the groundnut shell ash and the fiber, matrix is good for a certain weight percentage after that percentage it will not give the better results for the composite. Stress vs strain diagram of composites of 0, 3, 5, 7. Wt% of groundnut shell ash are shown in Figure 5. Stress – strain behaviour of the C2 composite shows more slope compared to other composites.

TABLE 1. Test Results of Composite

Sample	Polymer Matrix Composite	Tensile Strength (MPa)		Hardness Number		Impact Strength (J/mm^2)		Compressive Strength (MPa)	
		Strength	Average	RHN	AVG	Strength	AVG	Strength	AVG
		10.80		38		0.30		21.5	
C1	85% Epoxy+ 15% Banana fiber	9.60	10.21	33	35.6	0.20	0.252	19.6	20.7
		10.25		36		0.26		21	
		11.30		35		0.28		20.6	
C2	82% Epoxy+ 15% Banana fiber+ 3% groundnut shell ash	12.20	12.02	38	37.3	0.35	0.340	24.6	24.4
		12.60		39		0.39		28	
		10.80		31		0.56		26	
C3	80% Epoxy+ 15% Banana fiber+ 5% groundnut shell ash	9.6	10.30	34	32.6	0.52	0.512	21	23.6
		10.5		33		0.46		24	
		8.15		33		0.70		19.5	
C4	77.5% Epoxy+ 15% Banana fiber+ 7.5% groundnut shell ash	8.80	8.61	37	35.3	0.67	0.650	23.4	22.9
		8.90		36		0.60		26	

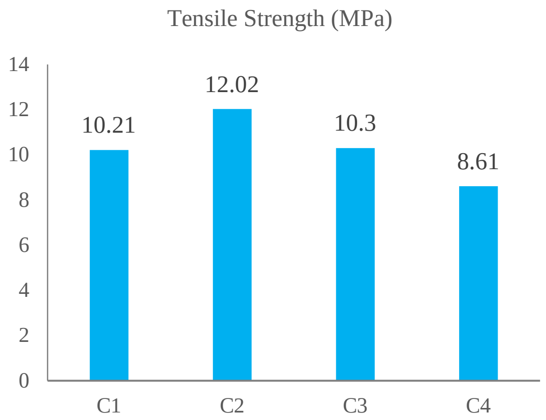

Figure 4. Variation of tensile strength of composites

This indicates that C2 composite have higher stiffness compared to other composites, compared to all specimens C2 composite have higher tensile strength.

Variation in the Rockwell hardness numbers are shown in Figure 6. It is observed that hardness number of the composite filled with 3 wt% ash (C2) have the higher hardness number compared to the other composites. It also shows that hardness number slightly increases with addition of 3% of filler material, further addition of the filler content decreases the hardness number. Change in the impact strength of NFC,'s were shows in Figure 7. Impact strength of NFC's were depending on the filler material. Increase of filler material slightly increases the impact strength of NFC's. It was found out that composite C4 have the higher impact strength.

Variation in the Rockwell hardness numbers were shown in Figure 6. It is observed that hardness number of the composite filled with the ash with 3 wt% (C2) have the higher hardness number compared to the other composites. It also shows that hardness number slightly increases with addition of 3% of filler material, further addition of the filler content decreases the hardness number. Change in the impact strength of NFC,'s are shown in Figure 7. Impact strength of NFC's were depending on the filler material. Increase of filler material slightly increases the impact strength of NFC's. It was found out that composite C4 have the higher impact strength.

Change in the compressive strength of the NFC's are shown in Figure 8. Groundnut shell ash influences the compressive strength of the composite. With addition of the ash compressive strength of the composites also increases. Composite C1 has the lower value compared to the other composites. Composite C2 has the higher compressive strength.

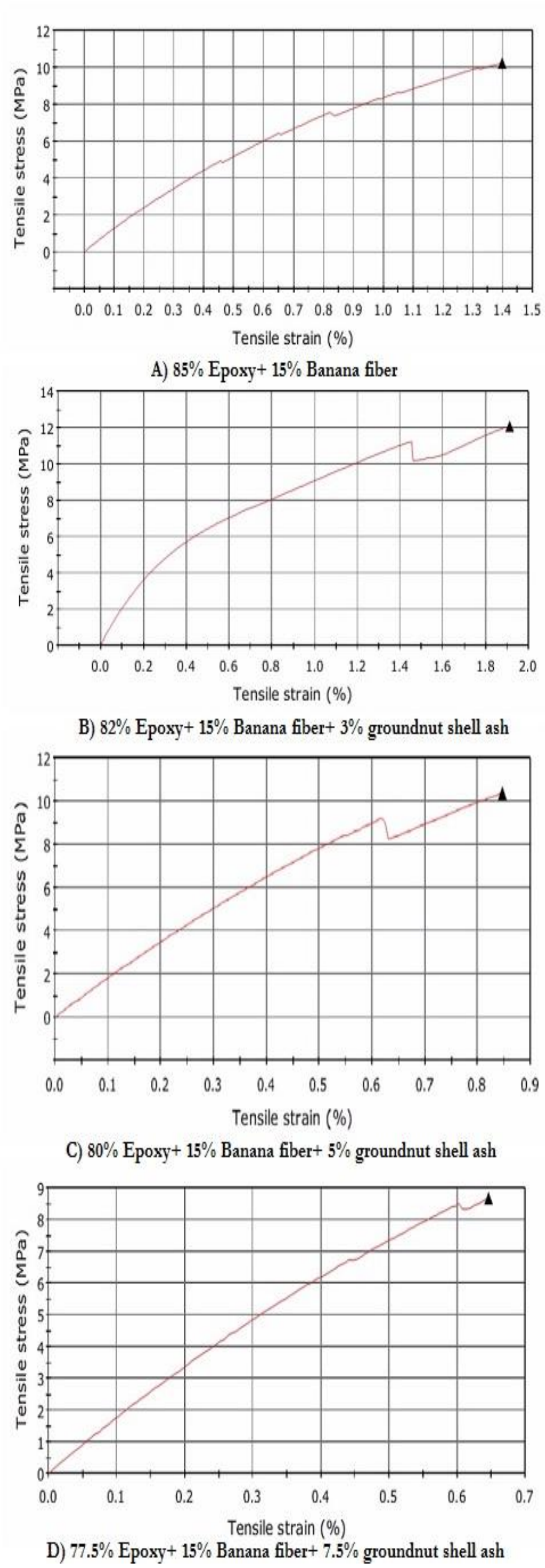

Figure 5. Stress Vs Strain Diagrams for composite materials

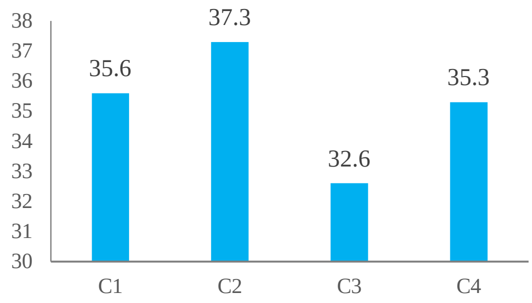

Figure 6. Variation of hardness number of composites

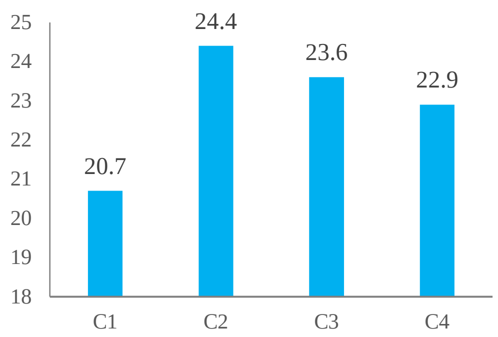

Figure 8. Variation of compressive strength of composites

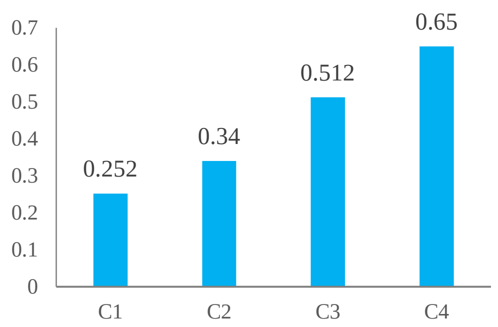

Figure 7. Variation of impact strength (J/mm^2) of composites

4. CONCLUSION

Epoxy based banana and banana filled with groundnut shell ash composites were prepared by conventional hand lay-up process. It is observed that incorporation of groundnut shell ash into the epoxy based banana fiber gives the good bonding between the matrix and reinforcement material. Addition of the groundnut shell ash to the epoxy / banana fiber improves the mechanical performance of composites. Among the all composites C2 composite had better mechanical behaviour excluding the impact strength. Interfacial bonding and stress concentration is the major parameters for a composite which are influencing the mechanical properties. The fiber pull-out and degree of adhesion are the parameters influencing impact strength of the composite, by this reason composite C4 had the better impact strength than other composites.

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چکیده

اثر افزودن مواد پرکننده به ترکیبات فیبر طبیعی به صورت آزمایشی مورد بررسی قرار گرفت. کامپوزیت ها با استفاده از روش دست خط معمولی تولید می شوند. تمام کامپوزیت ها با فیبر موز ثابت با قطر وزن 15 درصد و همچنین وزن متفاوت از (0، 3، 5، 7.5 درصد)، خاکستر پوسته زمین زمین به کامپوزیت اضافه می شود. کشش، سختی، ضربه و مقاومت فشاری برای یافتن رفتار مکانیکی کامپوزیت ها انجام می شود. آماده سازی و آزمایش بر اساس استانداردهای ASTM انجام شد. نتایج نشان می دهد که خواص مکانیکی با افزودن خاکستر پوسته زمین زمستانه به کامپوزیت فیبر موز بر پایه اپوکسی بهبود یافته است. کامپوزیت های فیبر طبیعی عمدتا در اتومبیل استفاده می شود (پانل های درب، قطعات داخلی و کابین روکش)، هوا فضا و مواد بسته بندی. الیاف طبیعی دارای مزایای بیشتری از قبیل کم هزینه، تخریب زیستی و چگالی کم نسبت به مواد غیر آلی هستند، تاثیر محیطی الیاف طبیعی نسبت به الیاف مصنوعی کمتر است.

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