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Fabrication and Testing of Reinforced Composites of Carbon and Agave Fibers

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***Abstract* – The growing environmental problems, the problem of waste disposal and the depletion of non-renewable resources have stimulated the use of green materials compatible with the environment to reduce environmental impacts. Therefore, there is a need to design products by using natural resources. Natural fibres seem to be a good alternative since they are abundantly available and there are a number of possibilities to use all the components of a fibre-yielding crop; one such fibre-yielding plant is Agave. The leaves of this plant can be utilized in many applications. The “zero-waste” utilization of the plant would enable its production and processing to be translated into a viable and sustainable industry. Agave fibres are characterized by low density, high tenacity and high moisture absorbency in comparison with other leaf fibres. These fibres are long and biodegradable. Therefore, we can look these fibres as a sustainable resource for manufacturing and technical applications.**

Agave Fibres exhibit high tensile strength and have low density. Because of this, historically, they were used in manufacturing twines and ropes. Agave plants have four times more cellulose than the fastest growing eucalyptus tree, and it effectively captures CO_2 from the atmosphere. When properly maintained, it requires irrigation only three to four times per year. Agave fibres have minimal environmental impact. The production does not need agricultural chemicals.

***Keywords* – Carbon Fibre, Agave Fibre, Low Density, High Tenacity.**

I. Introduction

The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibres of glass, carbon and Aramid the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armouring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc. Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures. Composites are now extensively being used for rehabilitation / strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity. Unlike conventional materials (e.g., steel), the properties of the composite material can be designed considering the structural aspects.

Properties of Carbon & Agave Fibres

Agave is perennial herbaceous plant with 5-6 ft for height and width belongs to family Asparagaceae. It is chiefly cultivated in coastal and tropical regions, mainly for its takila purpose. In India, it is cultivated on about 2250000 acres of land and is continuously increasing its production. Figures 5(a) and (b) show a Agave plant in the field; it is a short stem with dark green colour. First sprout of leaf looks decorative; later it converts into 6 ft. long, 5 to 3 inch wide sword shaped and numerous spirally arranged fibrous leaves edges as well as curved towards the cross section to maintain the stiffness of the leaf wide sword shaped and numerous spirally arranged fibrous leaves edges as well as curved towards the cross section to maintain the stiffness of the leaf.

Fig. 1. Agave plant

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Each Agave fruit has equal number of hexagonal sections on outer shell and does not depend on the size or shape. Now Malaysia is one of large producers in Asia as much as Hawaii. It produces a huge amount of waste material about 384,673 metric tonnes in year 2008. Productions of Agave leaf fibres are plentiful for industrial purpose without any supplementary addition and annually renewable and of easy availability. Agave is known as Nanas in Malaysia; basically they use different varieties for different purpose; for commercial purpose they use red Agave and green Agave; for edible purpose, they prefer Sarawak Agave and Morris Agave. Agave fruits contain many major and minor elements.

Table shows the percentage of elemental found in Agave fruit. It is source of bioactive compounds, particularly in proteolysis enzymes. Agave is very rich source of brome lain and other cysteine proteases are present in different part of Agave. Commercially, brome lain has been used in many food industries, cosmetics, and dietary supplements.

Table 1: Elemental Composition of Agave Plant

C	O	N	Ca	P	Fe	K	Mg	Cu	O/C ratio
73.13	24.17	2.70	0.00	--	--	--	--	0.00	0.33%
--	--	6.4-10	2.5-10	0.1-0.18	0.06-0.11	2.89	0.33	0.002-0.02	--

Table 2: Chemical composition of AGAVE

Cellulose content (%)	Hemi Cellulose (Wt.%)	Lignin Content (%)	Pectin (Wt. %)	Holo-cellulose	Moisture content (wt. %)	Ash (%)	Fat & Wax
85	--	12	--	--	--	--	--
70-82	--	5-12	--	--	11.8	--	--
67.1-69.3	--	14.5-15.4	--	--	--	1.21	--
68.5	18.8	6.04	1.1	--	--	0.9	3.2
69.5	--	4.4	1.2	--	--	2.7	4.2
69.5	--	4.4	1.1	--	--	0.9	3.3
70-80	--	5.0-12.7	--	--	11.8	--	3.3
74.33	--	10.41	--	80.68	--	4.73	--

Carbon Fiber

Composed of carbon atoms bonded together to form a long chain. A super strong material that's also extremely lightweight. Five times stronger than steel, two times stiffer, and about two-third times less in weight.

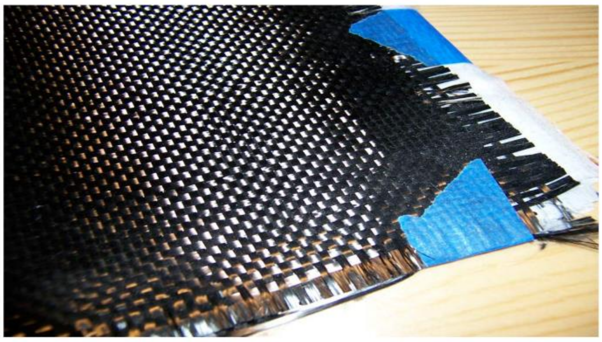

Fig. 2. Carbon fibre

Table 3: Physical and Mechanical properties of Carbon fibre

Fibre	Density (g/cc)	Tensile Strength (GPa)	Tensile Modulus (GPa)	Elongation %
Carbon PAN based Type 1	1.95	2.2	390	0.5
Carbon PAN based Type 2	1.75	2.7	250	1.0

1. *Properties of Carbon Fibre*

Carbon fibre reinforced polymer is an extremely strong and light fibre-reinforced plastic. High Strength to weight ratio. Rigidity, Corrosion resistance, Electrical Conductivity, Fatigue Resistance, Good tensile strength but Brittle, Fire Resistance/Not flammable &High Thermal Conductivity in some forms

Experimental Work

The details of processing of composites and the experimental procedures followed for their mechanical characterization. The raw materials used in this work are:

1. Glass Plates- 20x20 cm^2
2. Glass Strips- 2 cm
3. Beakers- 500 g
4. Stirring Rod
5. Epoxy Resin - LY556
6. Hardener - HY951
7. White Wax
8. OHP Paper
9. Glass fibre
10. AGAVE (Agave Fibre)

Epoxy Resin

Epoxy is either any of the basic components or the cured end products of epoxy resins, as well as a colloquial name for the epoxide functional group. Epoxy resins, also known as poly-epoxides, are a class of reactive pre-polymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homo-polymerization, or with a wide range of co-reactants including poly-functional amines, acids (and acid anhydrides), phenols, alcohols and thiols.

These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of polyepoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with high mechanical properties, temperature and chemical resistance. Epoxy

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has a wide range of applications, including metal coatings, use in electronics/electrical components/LED, high tension electrical insulators, paint brushes manufacturing, fiber-reinforced plastic materials and structural adhesives.

Epoxy resins are low molecular weight pre-polymers or higher molecular weight polymers which normally contain at least two epoxide groups. The epoxide group is also sometimes referred to as a glycidyl or oxirane group. A wide range of epoxy resins are produced industrially. The raw materials for epoxy resin production are today largely petroleum derived, although some plant derived sources are now becoming commercially available (e.g. plant derived glycerol used to make epichlorohydrin).

Hardener

In this work we used Hardener HY951.Low viscosity; unfilled epoxy casting resin system, curing at room temperature, has high filler addition possibility.

5. *Preparation of Composite Specimen*

Procedure for the preparation of above specimens:

- Initially wax has to be applied on the base of moulds for the easy removal of the specimen.
- In this case, we take 150ml of epoxy resin and 15ml of hardener. Now pour them into a glass beaker and mix it with a stirrer in order to avoid formation of bubbles.
- Glass mould is kept on a plane surface. The mixed solution is poured uniformly on to the mould and fibers (depending on the specimens) are placed in the mould and thoroughly mixed.
- After mixing of fibers with epoxy OHP sheet is to be placed on the mould and rolling is done. Place a weight on top of the mould for compaction for 24 hours.
- After 24 hours, remove the load on the top of the mould and place it in the furnace for post curing process at the temperature of 70^0C for some time and allowed to cool in the furnace itself. This helps in removing the specimen from the mould, to remove the wax content that was applied on the base of the mould and also the properties enhances by during this process.

Table 4 : Composition with respect to fibre percentage

Specimen	Carbon(gm)+ AGAVE(gm)
C1	8+2
C2	6+4
C3	4+6
C4	2+8

6. *Tests on Specimens*

1. Tensile test 2. Impact test 3. Flexural test

Tensile & Flexural test are performed on Universal testing Machine

Fig. 3. Universal Testing Machine

Fig. 4. Impact test Equipment & Specimens

7. *Results and Conclusions*

Table 5: Tensile test results

Name of the sample	Tensile strength (MPa)	Tensile modulus (MPa)
Agave fiber(2gms)+Carbon fiber(8gms)+Epoxy(200ml)+ Hardener(20ml)	35.65	5026.75
Agave fiber(4gms)+Carbon fiber(6gms)+Epoxy(200ml)+ Hardener(20ml)	51.84	5576.17
Agave fiber(6gms)+Carbon fiber(4gms)+Epoxy(200ml)+ Hardener(20ml)	36.08	3796.11
Agave fiber(8gms)+Carbon fiber(2gms)+Epoxy(200ml)+ Hardener(20ml)	35.05	4035.88

Table 6: Flexural test results

Name of the sample	Flexural strength (MPa)	Flexural modulus (MPa)
Agave fiber(2gms)+Carbon fiber(8gms)+Epoxy(200ml)+ Hardener(20ml)	215.76	11884.45
Agave fiber(4gms)+Carbon fiber(6gms)+Epoxy(200ml)+ Hardener(20ml)	99.43	14784.40
Agave fiber(6gms)+Carbon fiber(4gms)+Epoxy(200ml)+ Hardener(20ml)	82.70	14860.31
Agave fiber(8gms)+Carbon fiber(2gms)+Epoxy(200ml)+ Hardener(20ml)	63.42	12974.32

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Table 7: Impact test results

Mechanical Properties of Different Specimens

Table 8: Comparison of Mechanical properties of different specimens

Specimen	Agave(gm)+Carbon(gm)	Impact Load(J)	Tensile Strength(Mpa)	Flexural Strength(Mpa)
C1	2+8	2.2	35.65	215.76
C2	4+6	1.4	51.84	99.43
C3	6+4	2.0	36.08	82.70
C4	8+2	1.2	35.05	63.42

II. Conclusion

From the results obtained by the Tensile, Flexural and Impact Load tests done on the different specimens the following conclusions can be inferred:

- The specimen C2 (4gms of Agave + 6gms of Carbon) has tensile strength of 51.84 Mpa, which is relatively near to pure carbon fiber. Hence 40% of the carbon fiber can be replaced with Agave fiber for applications where tensile strength is the criteria of product design.
- The specimen C1 (2gms of Agave + 8gms of Carbon) has Flexural strength of 215.76 Mpa. Hence 20% of the carbon fiber can be replaced with Agave fiber for the applications where flexural strength is the criteria of the product design.
- From the above investigations the natural fiber Agave which is the abundantly available from Agave plants can replace Carbon fibers up to 30-40% of the fiber composition depending on the need of application of mechanical properties.

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