IJASRM

International Journal of Advanced Scientific Research and Management, Volume 3 Issue 10, Oct 2018

www.ijasrm.com

ISSN 2455-6378

Experimental Investigation and Comparison Of Mechanical Behavior Of Water Hyacinth Composite Materials

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Abstract

Fiber reinforced polymer composites plays major role in large variety of applications for their high specific strength and modulus. The fiber which serves as reinforcement in reinforced plastics . Although glass and other synthetic fiber reinforced plastics possess high specific strength and their field of application are limited because of their high cost. But natural fiber are strong, light weight and very cheap. Coir, jute and water hyacinth fibers are easily available in India. The present work describes the development and characterization of a hybrid composite material reinforced with coir, jute and water hyacinth fibers in various compositions like 100% JC, 75% JC and 25% WH, 50% JC and 50% WH, 25% JC and 75% WH, 100% WH. The developed composite material was subjected to tensile test, flexural test, impact test and moisture absorption test to study the performance characteristics for selection of the best composition of fiber for automobile components. It was found 75%JC and 25% WH fiber reinforced composite material will be a suitable alternative material for automobile components.

Keywords— *V_f –Fiber volume Fraction, W- Transverse Load in Flexural Test, L-Length of Flexural test specimen, b- width of test specimen, d- Thickness of Flexural test specimen, Y_{max} – Maximum Deflection in Flexural test, JC- Jute and coir, WH – Water Hyacinth.*

1. Introduction

Natural fibers cover a wide range of vegetable, animal, and mineral fibers. Commonly it refers to wood fiber and agro based bast, leaf, seed, and stem fibers. These natural (Chawla, K.K, 1987) fibers often contribute greatly to the structural performance of the plant and, when used in plastic composites, can provide significant reinforcement. The largest areas of recent growth in natural fiber plastic composites is the automotive industry, where natural fibers are advantageously used as a result of their low density and increasing environmental pressures. Most of the composites currently made with natural fibers are press-moulded, although a wide range of processes have been investigated.

Fibers are a hair-like material that are continuous filaments or are in discrete elongated pieces, similar to pieces of thread. They can be made into filaments, thread, or rope and can be used as a part of composites materials. Classification of fiber are natural fiber and man-made or synthetic fiber. Natural fibers can be classified according to their origin as 1.Animal fiber (Animal hair and Silk fiber), 2.Mineral fiber (Asbestos, Ceramic fibers and Metal fibers) and 3.Plant fiber (Seed, Leaf, Skin, Fruit and Stalk fibers).Water Hyacinth is a plant which grows rapidly in rivers and other water systems. This plant can float freely and can spread quickly. Modified WH fibers polymer composites on increasing of mechanical properties (H.S, Ramaswamy, B.M. Ahuja & S.Krishnamoorty, 1983) discussed. Now a days, water hyacinth has been utilized as an inexpensive and abundant resource in many countries and many products have been produced like basket work, fertilizer, paper, fibre board, yarn and rope, briquettes, and biogas.

2. Literature Review

Vegetable fiber offer several advantages in comparison with synthetic fibers. The vegetable fibres are biodegradable, non- abrasive to process equipment, are CO_2 neutral and can be used as acoustic and thermal insulators. Still they are light weight and high specific (Mukul Kant Paliwal, Sachin Kumar Chaturvedi,,2012) strength when compare to glass fibers.Other great advantages of the vegetable fiber are their low cost and the positive social impact. The study, LCA analysis of replacing glass fibers by jute fibers as reinforcement of composite materials to produce automotive structural components, case study demonstrate that jute fiber composite presents the best solution enhancing the environmental performance. It improve the performance of vehicle by reduce the fuel consumption due to reduction of weight (Prosenjith Saha, Suvendu manna, sougata roy chowdhury, Ramkrishna sen, Debasis Roy, & Basudam Adhikari.,2010).The coir (NABI SAHEB.D and JOG.J.P, 1999) fiber composite may be regarded as valid alternatives to replace some conventional materials nowadays used by the building industry, and also as furniture. For example, the rigid composites with less than 50% weight of coir fibers can be tailored to have tensile strength above 10MPa, which is higher than that of a low-density wood particle board with 5.5-9.7MPa. The coir fiber with Randomly oriented polyester composites are low- strength materials. The lack of an efficient reinforced by coir fiber is attributed to their low modulus of elasticity, in comparison with that of the bare polyester resin(Viswanathan.R, and Gothandapani.L, 1999).The fibers were tested in their natural air dry state and also in a alkaline environment by immersion up to 25 days in sodium hydroxide solution of pH value 11. The result indicates that the breaking tensile strength of fibers is quite high and that their loss of strength when immersed in alkaline medium varies from 5% for coir to 32% for jute. From this, came to know that the fiber loss their tensile strength when it is immersed in high concentrate alkaline medium for days (Roe,P. and Ansell,M., 1985).Particle boards were made from coir pith using phenol-formaldehyde and urea-formaldehyde resins. The mechanical properties (Monterio.S.N, Terrones L.A.H, J.R.M. D'Almeida.,2008), modulus of rupture, tensile strength both parallel to surface and perpendicular to surface, screw-holding capacity along face and along edge, nail-holding capacity along face and edge, were higher for particle boards made using a larger particle-size of coir pith at optimum level of process parameters.On treatment with 4% NaOH over 30 min duration at ambient temperature, the tensile strength was found to increase by 50% compared to untreated jute fibers and the elongation was found to increase by 54%. And the tensile strength was found to increase by 40%, the elongation was found to increase by 54% after treatment at ambient temperature at (90 ± 2˚C) duration of over 30min (Sinha, R.,2000).The hybrid composite reinforced with short sisal fiber and fir sawdust, tensile strength, Young's modulus, flexural strength, flexural modules and impact strength are found to be better at 15% sisal content in hybrid composite than other composition of fiber (Geethamma V.G, K. Thomas Mathew, R. Lakshminarayanan & Sabu Thomas.,1997).

Table1: Comparison of Coir and Jute Fiber with other Fiber Properties of Natural and Synthetic Fibers.

S.No	Fiber\ properties	Density g/cm^3	Elastic modulus GPa	Tensile strength GPa	Elongation %
1	Coir	1.33	4-6	0.14-0.15	15-40
2	Jute	1.45	10-32	0.45-0.55	1.1-1.5
3	Aramid	1.45	130	2.7-4.5	3.3-3.7
4	Carbon	1.8	260	3.5-5.0	1.4-1.8
5	E-glass	2.6	73	1.8-2.7	2.5
6	Sisal	1.45	9-12	0.56-0.64	3.0-7.0
7	Banana	1.35	8-20	0.52-0.75	1.0-3.5
8	Pineapple	1.44	43-81	0.41-1.62	0.8-1.6

3. Problem statement

The main objective of this work is to solve the problem of water hyacinth in local areas by finding a material use for the plant. Here the water hyacinth fibers are used as reinforcement in a composite with a Polymer matrix, also investigated the Impact strength of specimens and the bending strength of bar specimens.

4. Fabrication of Composites

4.1Mould Preparation

For the sample preparation the first and foremost step is the preparation of the mould which ensures the dimension of 300×300×45 mm the composite to be prepared. Mould was prepared with wooden pieces and side surface and bottom surface was covered by thin plastic cover. A mould was prepared to fabricate the hybrid composite material in following composition.

4.2 Volume of Fiber

1. $V_{coir\ fiber=20\%} + V_{jute\ fiber=80\%} = V_f$
2. $V_{jute\ \&\ coir\ fiber=75\%} + V_{water\ hyancith\ fiber=25\%} = V_f$
3. $V_{jute\ \&\ coir\ fiber=25\%} + V_{water\ hyancith\ fiber=75\%} = V_f$
4. $V_{jute\ \&\ coir\ fiber=50\%} + V_{water\ hyancith\ fiber=60\%} = V_f$
5. $V_{jute\ \&\ coir\ fiber=0\%} + V_{water\ hyancith\ fiber=100\%} = V_f$

4.3 Polymer Matrix Preparation

Polyester resin is used as polymer matrix, cobalt Naphthalene is used as accelerator and Methyl Ethyl Ketone peroxide is used catalyst. For 250grams of resin, take 1ml accelerator and 2ml catalyst, it gives gel time of 5hrs. Based on the requirement of polymer matrix above specified mixing ratio of resin, accelerator and catalyst is used.

4.4 Fiber Content Calculation

Total Volume of Composite material = 30*30*0.3 = 270 $cm^{3;}$ Fiber Volume Fraction V_f = 30%; Volume of fiber = 270*0.3 = 81cm^3; Density of Coir fiber = 1.33 g /cm^3; Density of Jute fiber = 1.45g /cm^3; Density of Water Hyacinth fiber = 1.11g/cm^3.

4.5 Matrix Content Calculation

Total Volume of Composite material = 30*30*0.3 = 270 cm^3 Matrix Volume Fraction V_f = 30%

Volume of matrix = 270*0.7 = 189 cm^3Density of Polyester matrix = 1.29g /cm^3

Mass of polyester matrix = 1.29*189 = 243.81 g = 245 g (app.)

4.6 Composite Specimen Preparation

To prepare the composite specimen Hand lay-up technique was used. Place the plastic sheets in bottom of the mould and apply the thin coat of wax over the mould inner surface to avoid the sticking of composite material in mould and plastic cover. Put the fiber in to the mould in random orientation and slowly poured the polymer matrix mixture in to the mould. Gently roll the roller throughout the mould for remove the air gaps and void, because, presence of air gaps inside the structure leads to weaken the composite material. After the even fit of fiber and polymer matrix in the mould stop the roller action and cover the top surface with thin wax coated plastic sheet. Place the weight on the mould to apply the pressure on the composite material to strengthen it. The composite sheet takes 24 hrs for curing in room temperature. Then the samples were cut into desired dimensions for experimental purposes as per the ASTM standards.

Table 2: ASTM Standard for Test

S.No	Test	ASTM Standard	Specimen Size (mm)
1	Tensile Test	D 3039	250 X 25 X 3
2	Flexural Test	D 790	125 X 13 X 3
3	Impact test	D 4812	64 X 13 X 3
4	Moisture Absorption test	D5229	100 X 100 X 3

5 Testing of Composite Materials

5.1 Tensile test

Tensile test is performed to determine several mechanical properties. In this testing method , a standard specimen of ASTM D 3039 is subjected to a gradually increasing axial tensile load until it fractures with speed of 2mm/min. Universal testing machine is used to perform the tensile test.

Cross section area of specimen = 54 mm^2; Initial length of specimen = 100 mm; Stress or Tensile strength = Load / cross section area; Strain = Change in length / Initial Length; Axial modulus or young's modulus = Stress / Strain

Table 3: Tensile Test – 80% Coir & 20% Jute (100% JC)

`S.No	Load in [N]	Length in [mm]	Stress in [N/mm²]	% Strain	Axial Modulus (Gpa)
1	4.513	0	0.06	0	0
2	7.456	0.01	0.099	0.007	0.01414
3	9.32	0.01	0.124	0.007	0.017714
4	90.35	0.09	1.205	0.06	0.020083
5	92.116	0.09	1.228	0.06	0.020466
6	92.41	0.1	1.232	0.067	0.018388
7	96.138	0.1	1.282	0.067	0.019134
8	96.727	0.1	1.29	0.067	0.019253
9	98.394	0.11	1.312	0.073	0.017972
10	99.572	0.11	1.328	0.073	0.018191
11	923.71	1.01	12.264	0.667	0.018386
12	924.985	1.01	12.316	0.673	0.0183
13	927.437	1.01	12.333	0.673	0.018325
14	930.479	1.02	12.366	0.673	0.018374
15	933.422	1.02	12.406	0.68	0.018244
16	1807.689	2.45	24.103	1.633	0.014759
17	1807.885	2.46	24.105	1.64	0.014698
18	1808.866	2.46	24.118	1.64	0.014706
19	1810.73	2.46	24.143	1.64	0.014721
20	1812.398	2.47	24.165	1.647	0.014672

Average axial modulus = **0.017396**GPa

Flexural properties are determined by ASTM Test method D790.In this testing method , the composite beam specimen of rectangular cross section is loaded in three-point bending mode. The loading on the middle of member towards downwards and causing bending, the specimen is subjected to tension at its lower surface. The load and the deflection of the specimen are measured. The stress at fracture in bending is known as flexural strength or Transverse rupture strength. Flexural strength = 6WLY / bd^3 and Transverse modulus = $WL^3 / 4Y_{max}bd^3$;

Table 4: Flexural Test – 80% Jute & 20% Coir

S No.	Load [N]	Length[mm]
1	1.962	0.01
2	5.003	0.13
3	10.006	0.78
4	15.107	0.96
5	20.012	1.42
6	25.114	1.62
7	30.902	1.87
8	34.237	2
9	37.376	2.15
10	40.515	2.3
11	44.439	2.5
12	48.658	2.79
13	50.62	3.11
14	52.778	3.25
15	55.721	3.53
16	57.977	3.75
17	59.743	4
18	62.235	4.15
19	65.556	4.22

Transverse modulus = $WL^3 / 4Y_{max}bd^3$ = 2446.0913GPa.

Table 5: Flexural Test – JC 75% & WH 25%

S. No	Load [N]	Length [mm]
1	0	0
2	2.158	0.01
3	5.003	0.15
4	10.006	0.79
5	15.009	1.02
6	20.012	1.33
7	25.016	1.59
8	30.019	1.89
9	35.022	2.22
10	40.025	2.57
11	45.028	2.97
12	50.031	3.37
13	55.132	3.83
14	60.037	4.33
15	65.138	4.92
16	68.436	5.66
17	71.907	6.1
18	73.005	6.35
19	75.025	6.685
20	78.862	6.325

Transverse modulus = $WL^3 / 4Y_{max}bd^3$ =2727.2755 GPa

Table 6: Flexural Test – JC 50% & WH 50%

S. No	Load [N]	Length[mm]
1	0	0
2	2.06	0.01
3	6.573	0.3
4	12.557	0.8
5	18.541	1.1
6	23.25	1.4
7	33.55	1.75
8	37.67	1.9
9	40.81	2.03
10	46.499	2.25
11	55.623	2.6
12	60.43	2.8
13	64.452	3
14	66.414	3.1
15	68.474	3.2
16	70.828	3.35
17	72.135	3.5
18	75.652	3.7
19	78.456	3.885
20	80.529	4.127

Transverse modulus = $WL^3 / 4Y_{max}bd^3$ =2309.908GPa

Table 7 : Flexural Test – JC 25% & WH 75%

S. No	Load [N]	Length[mm]
1	0	0
2	3.139	0.05
3	7.161	0.65
4	12.066	0.9
5	16.579	1.1
6	20.895	1.56
7	24.917	1.73
8	28.841	1.91
9	36.689	2.3
10	40.908	2.54
11	45.42	2.75
12	50.914	3.04
13	54.74	3.25
14	60.92	3.58
15	66.512	3.9
16	69.749	4.11
17	72.005	4.25
18	75.537	4.5
19	77.009	4.61
20	78.676	4.74

Transverse modulus = $WL^3 / 4Y_{max}bd^3$ = 1996.161 GPa

IJASRM
International Journal of Advanced Scientific Research and Management, Volume 3 Issue 10, Oct 2018
www.ijasrm.com
ISSN 2455-6378

Table 8 : Flexural Test – WH 100%

S. No	Load in [N]	Length in [mm]
1	0	0
2	2.649	0.05
3	5.003	0.23
4	6.475	0.5
5	9.025	1.04
6	13.047	1.35
7	15.402	1.55
8	18.05	1.93
9	20.797	2.25
10	21.68	2.5
11	25.31	2.89
12	28.449	3.25
13	30.117	3.49
14	31.196	3.7
15	32.569	4
16	33.06	4.1
17	33.256	4.25
18	32.667	4.4
19	31.196	4.47
20	35.128	4.854

Transverse modulus = $WL^3 / 4Y_{max}bd^3$ = 2213.794333GPa

5.2 Impact Test (Charpy)

In this impact test, the ASTM D4812 un-notched specimen is clamped into the pendulum impact test fixture. The thickness of specimen was increased to 7mm for obtaining the energy observed value in analog dial of impact testing machine because Impact strength of these composite materials is very low.

Impact strength = Observed Energy / Cross sectional area

Table 9: Izod Impact Value for 3 mm Thick Specimen in J

Sl.No.	Sample Number	Impact Value for 3 mm Thick
1	I_1	1
2	I_2	0.6
3	I_3	0.6

Average = 0.733 J

Table 10: Izod Impact Value for 3 mm Thick Specimen in J

S..No	Sample Number	Impact Value for 3 mm Thick
1	I_1	0.6
2	I_2	0.6
3	I_3	0.62

Average = 0.0.606 J

Table 11: Izod Impact Value for 3 mm Thick Specimen in J

S.No	Sample Number	Impact Value for 3 mm Thick Specimen
1	I_1	0.5
2	I_2	0.5
3	I_3	0.52

Average = 0.506 J

Table 12 : Izod Impact Value for 3 mm Thick Specimen in J

S.No	Sample Number	Impact Value for 3 mm Thick Specimen in J
1	I_1	0.3
2	I_2	0.28
3	I_3	0.3

Average = 0.293 J

5.3 Moisture Absorption Test

Moisture Absorption test of Matrix Composites (ASTM D5229) is a gravimetric test method that determines change over time of moisture content by measuring the total mass change. In this testing method, the side edges of test specimen are sealed with wax to prevent moisture absorption through the sides of the specimen . The specimens are dried and then weighed on an analytical balance and then placed in the appropriate environment condition. The specimens are removed from the conditioning environment periodically and weighed. This procedure is repeated until there is no appreciable increase in specimen weight.

Table 13: Moisture Absorption test - 80% & COIR 20% (100% JC)

S.No	Time in hrs	Weight in g	% of Moisture Absorption
1	0	10	0
2	1	10	0
3	3	10	0
4	6	10.2	2
5	9	10.2	2
6	12	10.3	3
7	15	10.4	3
8	18	10.5	5
9	21	10.6	6
10	24	10.6	6

Table 14 : Moisture Absorption test –75% JC&25% WH

S.No	Time in hrs	Weight in g	% of Moisture Absorption
1	0	9.8	0
2	1	9.8	0
3	3	9.9	1.01
4	6	9.9	1.01
5	9	9.9	1.01
6	12	10	2.04
7	15	10.1	3.06
8	18	10.1	3.06
9	21	10.2	4.08
10	24	10.3	4.08

Table 15 : Moisture Absorption test –50% JC&50% WH

S.No	Time in hrs	Weight in g	% of Moisture Absorption
1	0	9.7	0
2	1	9.7	0
3	3	9.7	0
4	6	9.7	0
5	9	9.8	1.03
6	12	9.8	1.03
7	15	10	3.09
8	18	10.1	4.12
9	21	10.1	4.12
10	24	10.2	5.15

Table 16 : Moisture Absorption test –25% JC&75% WH

S.No	Time in hrs	Weight in g	% of Moisture Absorption
1	0	9.6	0
2	1	9.6	0
3	3	9.6	0
4	6	9.7	1.04
5	9	9.8	2.08
6	12	9.8	2.08
7	15	9.9	3.125
8	18	10	4.166
9	21	10.1	5.208
10	24	10.1	5.208

Table 17 : Moisture Absorption test –100% WH

S.No	Time in hrs	Weight in g	% of Moisture Absorption
1	0	9.3	0
2	1	9.3	0
3	3	9.4	1.07
4	6	9.4	1.07
5	9	9.5	2.15
6	12	9.5	2.15
7	15	9.6	3.22
8	18	9.7	4.34
9	21	9.7	4.34
10	24	9.8	5.37

6. Results and Discussion

From the flexural test it is noted that the composite material from the composition of 75% Jute and Coir and 25% WH has high flexural strength and flexural modulus. From the impact test it is observed that the composite material from the composition of 20% Coir and 80%jute has high impact strength. It is observed that by increasing percentage of water hyacinth from 25% flexural modulus, flexural strength and impact strength are decreasing. From the moisture absorption test it is found that that the composite material from the composition of 75% Jute and Coir and 25% WH has less percentage of moisture absorbed. It is noticed that by increasing percentage of water hyacinth from 25% the moisture absorption % also increases. From the experimental result, 75% Jute & Coir with 25% water hyacinth suggested for automobile components like silencer guard and mudguard.

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