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Effect of Various Fibers on Mechanical Properties of Bio-Composite Materials

Ganesan C[1], Yash Pal[2], R. Sathish Babu[3], Kalpit K[4]
[1, 2, 3] School of Aeronautical Sciences, Hindustan University, Chennai-603103
[4]School of Engineering and Technology, MATS University, Raipur-492001

Abstract:- This study investigated the effects of various natural fibers in a Bio-composite material. Different types of fibres viz sawdust, straw, rice husk and baggasse were used to prepare the samples and mechanical characterization were carried out. It was aimed to see the possibility of using bio-composite fibers, regarded as waste materials, in producing the highest mechanical properties. The tensile strength of the composites was measured with a universal testing machine in accordance with the ASTM Standards. The results had revealed that the Saw dust and baggasse fiber composite has shown improvement in mechanical properties, especially for tear resistance and tensile strength. However, the comparison of tensile strength with tear resistance results did not report any direct relationship between these characteristics.

Keywords:- Bio-Composite, Tensile strength, Shore Hardness, Tear Resistance and Mechanical properties.

I. INTRODUCTION

Fiber composites are materials made up of plastic and multiple types of fibers. Composites using fiber glass, carbon fiber or, for example, Kevlar in combination with various types of plastic are already in use in industry. Bio-composites are a type of fiber composites that combine bio-degradable fibers with a type of biosynthetic plastic. Bio composite materials in aircraft industry are attractive because it reduces the airframe weight and enables to settle fuel economy. It has its applications even in primary structure of the aircraft like wings and fuselage. Over the recent years there has been a significant increase in the use of composite materials due to its high performance in the aerospace industry. The performance of composite materials in aerospace application is superior to conventional structural material such as steel and aluminum. Taking this into account eco-friendly materials are fabricated using recycled waste materials like sawdust, straw, rice husk and baggasse. Silwa et al [1] investigated about a new family of wood polymer composites with thermoplastic elastomer matrix (pebax copolymers) instead of commonly used WPC matrices. They evaluated fibers/matrix interaction by differential scanning calorimetry (DSC), infrared spectroscopy (IRTF) and scanning electron microscopy (SEM) and they assessed mechanical properties, through the tensile test. They also observed that DSC, IRTF and SEM measurements confirmed the presence of strong interface interactions between polymer and wood. Younesi and Bahrololoom [2] investigated about the effects of pressure and temperature in hot press molding on the mechanical properties of polypropylene–hydroxyapatites composites with two different types of silanated and unsilanated hydroxyapatites. They evaluated density, crystallinity, ultimate tensile strength, Young's modulus, and impact resistance for the two types of composites. They showed that effects of increasing pressure and temperature on the mechanical properties of polypropylene–silanated hydroxyapatite were less than their effects on the mechanical properties of polypropylene–unsilanated hydroxyapatites.

Yang et al [3] determined physical properties and mechanical properties of lignocellulosic filler reinforced polyolefin bio-composites. They used polyolefin as the matrix polymer and rice-husk flour as the reinforcing filler. Wood floor was also used as reinforcing filler. They showed that the thickness swelling and water absorption of the bio-composites slightly increased as the filler loading increased, but to a negligible extent as compared with the wood-based composites (particleboard and fiberboard) and the solid woods (red pine and birch). They concluded that these bio-composites are suitable to be used for the interior of bathrooms, wood decks, food packaging. Haq et al [4] investigated about the Hybrid bio-based composites and they showed that the synergy between natural fibers (industrial hemp) in a nanoreinforced bio-based polymer can lead to improved properties while maintaining an environmental appeal. Also they showed that Bio-based resins obtained by partial substitution of unsaturated polyester (UPE) with epoxidized soybean oil (EMS) increase toughness but compromise stiffness and Hygro-thermal properties. Hosseinpourpia [5] studied the performance of silica nano-particles combined with waste paper pulp fibers (sulfite fibers). They conducted different mechanical (compressive and flexural strengths and bending performance), durability (water absorption), physical (bulk density and flow ability), and micro structural (scanning electron microscopy) tests and examined the properties of manufactured green composites. Their results showed that the mechanical properties of cement-based composites containing a ternary system of ''natural waste fiber–silica nano-particle cement'' also adding silica nano-particles allows the development of green cement-based composites and movement toward sustainable development in the concrete industry. Christian and Billington [6] studied the mechanical behavior of bio-composites made from cellulose acetate, polyhydroxybutyrate materials and hemp fiber (fabric) experimentally. Wang et al [7] investigated the effect of HP loading on the curing characteristics and mechanical properties of filled SBR and EPDM composites using tetra sulphide as coupling agent. They showed that the dynamic mechanical analysis indicated that the composites exhibited higher payne effect and storage modulus. Yue and Weimin [8] developed a micromechanical model to predict the elastic modulus of hydroxyl appetite whisker reinforced polymer biocomposites based upon the elastic properties of each phase and the reinforcement volume fraction, morphology and preferred orientation. Averousand and Digabel [9] studied about thermal and mechanical behavior of processed biocomposites, created by extrusion and injection molding. Tajeddin et al [10] investigated the mechanical properties of kenaf cellulose /cope biocomposites. They showed that kenaf cellulose /cope biocomposites shows better mechanical properties when compared with other natural fiber composites.

II. MATERIALS AND METHODS

A. Sample Preparation

Raw materials which are used to present experimental work restricted to only the waste recycled materials. So the material such as Straw, Rice Husk, Saw Dust and Baggasse are used because of their bio-degradability, strength to weight ratio and also their flexible nature. Straw is hay collected from a nearby farm after drying it evenly at a constant temperature of 35°C. The main reason to prefer straw is that it was hard, strong and very flexible. Sawdust is a material that binds very hard to its matrix phase, and we had to powder it to avoid any lumps in it. Baggasse is the dried form of sugarcane. We had to chop the sugarcane and dry it at a constant temperature of 38°C and when powder it evenly for our resin. The reinforcement phase used here in the bio-composite is the natural fibers and the matrix phase used is the polyvinyl alcohol. The sample is prepared in the form of a sheet of thickness 3mm.

B. Preparation of Mould

For the preparation of mould we used a steel sheet and foam board. The main reason for using steel sheet was that it can bear more stresses than the glass and it will not crack as the glass do. And for the steel plate the border will not allow the molten PVA to flow out which was constructed by using the Foam board. The thickness of the border is of around 6mm, so that a 3mm sheet of bio-composite using the recycling materials was formed if the raw molten sample is filled over 6mm thickness mold. The border is the foam board as said and it is cut for the breath of 10mm and it is stick to the steel plate using the fevicol synthetic resin glue as presented in the Fig. 1.

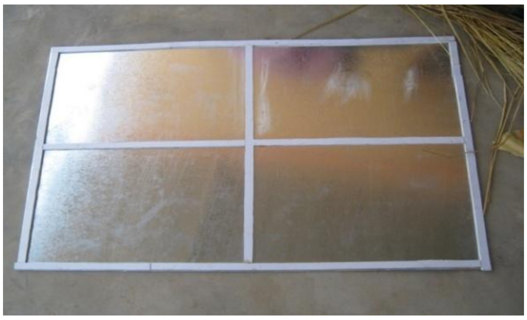

Fig. 1: Layout and Setup of Mould

C. Fabrication Process

Hand lay-up method was used for the manufacturing of the bio-composite sheet. Fibers have to be grown and processed very economically and at competitive prices, as compared with man-made fibers produced by modern industries. Therefore the first processing stage has to take place in the vicinity of the farms.

D. Materials Used

The various materials required for this process are polyvinyl alcohol which is the resin material, Glycerol, Urea, Sodium hydroxide and various natural recycling materials such as rice husk, saw dust, sugarcane bagasse, and straw. Polyvinyl alcohol is usually in the form of powder or granule form which will be converted to hot liquid during fabrication by the addition of hot water. Next glycerol is added to the hot molten PVA which will be used as a binding agent.

E. Preparation of the Resin

A vessel containing 500ml of water is taken and it is boiled to the temperature of 100°C. Then the polyvinyl alcohol of about 70g which is usually in the granule form is added to the boiling water and stirred constantly using the metal stirrer.

F. Addition of Waste Recycling Materials

Straw is used as the long continuous fibers rather all the other three fibers will be in the discontinuous form of arrangement. Sawdust and rice husk have been already in the ground powder form, hence it was added directly to the molten PVA gel without any further grinding but Sugarcane bagasse was grounded properly until it turned into a nice powder form before it was added.

G. Casting of Sheets

In case of Rice husk, Sawdust and Bagasse the prepared resins along with the powdered fibers were poured over the mold which was lubricated properly that ensures the smooth extraction of the sheet. But In case of Straw, First one layer of the resin of molten PVA gel is poured over the mold and then the straw fiber is aligned over the mood as close as possible. Then over the fiber the second layer of the resin PVA is poured and the process continued. Thus the mould is filled with the resin and the matrix. Usually the mould is of 6mm thickness and it is fully filled. And then it is let under the open atmosphere under the sunlight to dry.

H. Drying

The mould was allowed to dry under the sunlight for the period of 2days. Care should be taken so that there should not be any extensive drying due to which the mold may stick to the surface and will become hard to remove from the mold after drying. Also extensive drying leads to the formation of the voids. The test result of straw fiber samples is presented in Table 1.

Table 1: Various Test Results of Straw Fiber Sample

Properties	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
Tensile Strength (N/mm^2)	3.4	4.02	4.35	3.63	3.7	3.4
Hardness (Shore A)	68	80	70	80	72	68
Tear Resistance (N/mm)	32.14	26.76	34.74	29.15	28.31	32.41

I. Extraction of Sheets

After the mold was dried under the sunlight the bio-composite sheet made of recycling materials was removed from the mold. During the drying process the thickness of the resin and fiber mixture will gets reduced. This is due to the evaporation of the water from the mixture. Roughly there will be about 50% reduction in the thickness. The sheet is first sliced in the border and then removed slowly with care so that there will not be any wear and tear on the sheet as shown in Fig. 2.

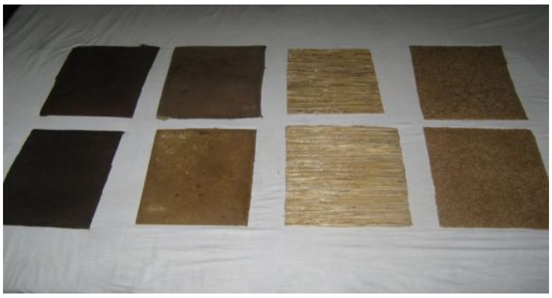

Fig. 2: Bio-Composite Sheet with Different Types of Fibers

J. Tensile Test

During the tensile test, the ASTM standard D3039 specimens were striped at two fixtures of the machine and load is applied as per the ASTM standard recommends tilling the sample was fooled into two segments. The test result for Rice Husk fiber samples is presented in Table 2.

Table 2: Various Test Results of Rice Husk Fiber

Properties	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
Tensile Strength (N/mm^2)	3.32	3.94	4.27	3.55	3.62	3.32
Hardness (Shore A)	57	69	59	69	61	57
Tear Resistance (N/mm)	36.77	39.08	37.12	38.12	39.21	36.77

K. Hardness Test

Hardness test is performed on the material according to the ASTM D2240 standards which is used to determine the relative hardness of materials. The test measures the penetration of a specified indentor into the material under specified conditions of force and time. The test result for Sawdust fiber samples is presented in Table 3.

Table 3: Various Test Results of Saw Dust Fiber

Properties	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
Tensile Strength (N/mm^2)	8.316	8.316	8.316	8.316	8.316	13.5
Hardness (Shore A)	68	80	70	80	72	68
Tear Resistance (N/mm)	110.7	136.7	122.4	109.1	104.1	110.7

L. Tear Resistance Test

The tear Resistance test is performed on the material according to the ASTM D1004 standards for measuring the ultimate force required to tear film or sheet. The procedure of testing involves measuring the average thickness of the specimen and it is placed in the grips of the testing machine and pulled at a rate of 2in. Per minute until rupture. The test result for bagasse fiber samples is presented in Table 4.

Table 4: Various Test Results of Baggasse Fiber

Properties	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
Tensile Strength (N/mm^2)	6.93	7.55	7.88	7.16	7.23	6.93
Hardness (Shore A)	73	85	75	85	77	73
Tear Resistance (N/mm)	88.60	90.95	88.99	89.98	91.09	88.63

III. RESULTS AND DISCUSSIONS

A. Tensile Test

The tensile test results performed on the bio-composite material are presented in the Fig. 3. Tensile strength of rice husk fiber varies linearly with load. However this variation for the sawdust, bags and straw fiber has not significant effect over the strength. The variation of the rice husk fiber is attributed to the increased surface area for fiber in composite material. The increased fiber surface area also gives significant load distribution in the matrix.

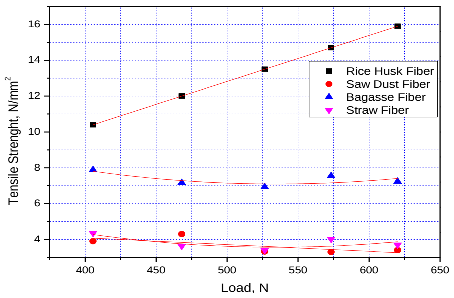

Fig. 3: Tensile Strength Variation for Different Types of Fiber

To compare the results for tensile strength variation for all four types of fibers, an average tensile strength of rice husk, saw dust, baggasse and straw fibers are reported in the Fig. 4. It has been observed from the figure that the average tensile strength of seeing dust fiber is highest among all types of fiber.

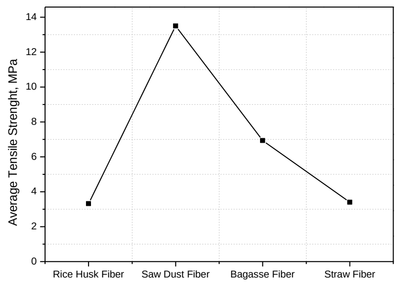

Fig. 4: Average Tensile Strength Variation for Different Types of Fiber

B. Tear Resistance Test

Results from tear resistance test have been summarized in Fig. 5. The reported results shown that the how well a fiber material resists the growth of any damage when under tension; the saw dust fiber has shown an excellent tearing resistance over all the other types of fiber. As the loading is increased in each test the tearing resistance also increasing for the saw dust fiber composite.

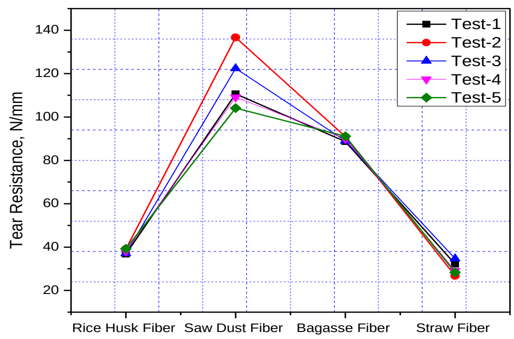

Fig. 5: Tear Resistance Variation for Different Types of Fiber

A comparison has been made among all the types of fiber for average tearing resistance variation. The saw dust fiber has been reported highest tearing resistance among all the types of fibers as shown in Fig. 6. Comparison of tensile strength with tear resistance results did not report any direct relationship between these characteristics. Tensile properties of these bio-composite are dependent on density, whereas the results of their experiment shown depending on the fiber surface area.

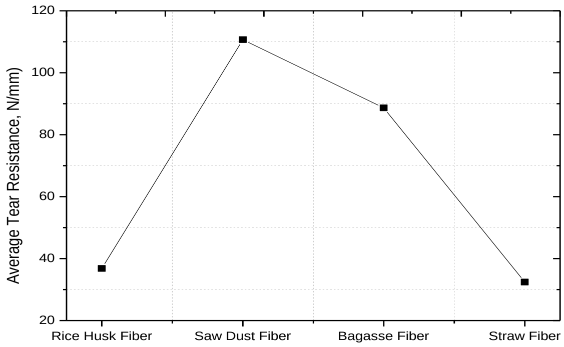

Fig. 6: Average Tear Resistance Variation for Different Types of Fiber

C. Shore Hardness Test

Fig. 7 shows the relationship between hardness and different fiber (rice husk, saw dust, baggasse and straw fibers), which were added to the resin. The results had reported that the hardness increases for all groups of fiber with multiple tests. For comparison among all the types of fiber, it has been reported that baggasse fiber reported highest average hardness of 73A as shown in the Fig. 8.

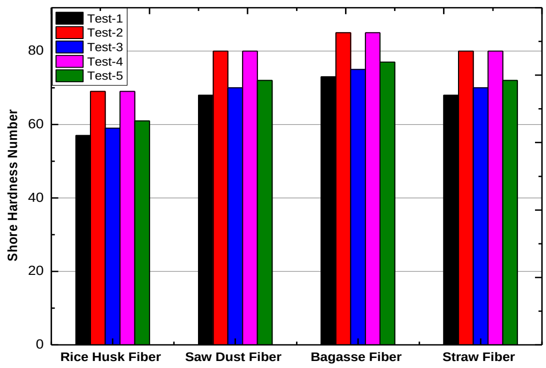

Fig. 7: Shore Hardness Variation for Different Types of Fiber

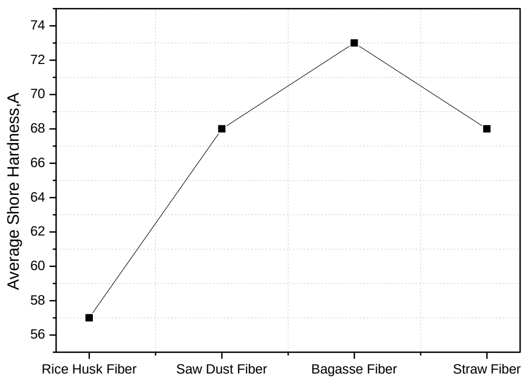

Fig. 8: Average Shore Hardness Variation for Different Types of Fiber

IV. CONCLUSIONS

A series of mechanical tests were performed to investigate the tensile strength, tear resistance and hardness of different types of bio-composite materials. It has been concluded from the results that:

1. Tensile strength of rice husk fiber varies linearly with load. However this variation for the sawdust, bags and straw fiber has not significant effect over the strength. It has been observed that the average tensile strength for saw dust fibre is highest among all types of fibres.
2. The saw dust fiber has shown an excellent tearing resistance over all the other types of fiber. As the loading is increased in each test the tearing resistance also increasing for the saw dust fiber composite. Comparison of tensile strength with tear resistance results did not report any direct relationship between these characteristics.
3. The baggasse fibre bio-composite has been reported highest average hardness of 73A.

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REFERENCES

[1] Sliwa, F., Bounia, N. E., Charrier, F., Marin, G., and Malet, F., “Mechanical and interfacial properties of wood and bio-based thermoplastic composite,” Composites Science and Technology, Vol. 72, pp. 1733–1740, 2012.

[2] Younesi. M, and Bahrololoom, M. E., “Effect of temperature and pressure of hot pressing on the mechanical properties of PP–HA bio-composites”, Materials and Design, Vol.30, pp. 3482–3488, 2009.

[3] Yang, H.S., Kim, H.J., Park, H.J., Lee, B. J., and Hwang, T. S., “Water absorption behavior and mechanical properties of lignocellulosic filler–polyolefin bio-composites”, Composite Structures, Vol.72, pp. 429–437, 2006.

[4] Haq, M., Burgueño, R., Mohanty, A.K., and Misra, M., “Hybrid bio-based composites from blends of unsaturated polyester and soybean oil reinforced with nanoclay and natural fibers”, Composites Science and Technology, Vol. 68, pp. 3344–3351, 2008.

[5] Hosseinpourpia, R., Varshoee, A., Soltani, M., Hosseini, P., and Tabari, H. Z., “Production of waste bio-fiber cement-based composites reinforced with nano-SiO2 particles as a substitute for asbestos cement composites”, Construction and Building Materials, Vol.31, pp. 105–111, 2012.

[6] Christian, SJ and SL Billington, "Sustainable Biocomposites for Construction," Proceedings for Composites & Polycon, American Composites Manufacturers Association, Tampa, FL, January, 2009.

[7] Wang, Jie., Wu, Weidong., Wang, Wencai Zhang, and Jianchun, “Preparation and characterization of hemp hurd powder filled SBR and EPDM elastomers, Journal of Polymer Research, Volume 18, pp. 1023-1032, 2011.

[8] Yue, Weimin “Micromechanical Modeling of Hydroxyapatite Whisker Reinforced Polymer Composites and Cortical Bone Tissue, PhD Dissertation, University of Notre Dame, 2007.

[9] Averousand F. and Le Digabel “Properties of biocomposites based on lignocellulosic fillers,” Carbohydrate Polymers, Vol. 66, pp. 480–493, 2006.

[10] Behjat Tajeddin, Russly Abdul Rahman and L. C. Abdulah “Mechanical and Morphological Properties of Kenaf Cellulose/LDPE Biocomposites,” American-Eurasian J. Agric. & Environ. Sci., Vol. 5, pp. 777-785, 2009.