

Mechanical Properties of Agricultural Byproduct Polymer Composites

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Abstract

Natural fibers from agricultural wastes are finding their importance in the polymer industry due to the many advantages such as their light weight, low cost and being environmentally friendly. Rice straw is agricultural byproducts which is vegetative part of the rice plant and available in Bangladesh. As a type of natural fiber obtained from agricultural byproducts, rice straw can be used as filler in composites materials in various polymer matrices. In this study, an attempt has been made to fabricate rice straw fiber based polymer composite and evaluation its mechanical performances. For this composite preparation, rice straw fibers were used as reinforcement and the epoxy resin (ADR 246 TX) was used as the matrix. The fabrication of the composite is done by using hand layup techniques. Different fiber weight % (10, 20, 30 and 40 weight %) are used to prepare the composite. The composite thus made was tested for its mechanical properties like tensile test, flexural test, and impact test. Results showed that the tensile strength of the rice straws composites increased with increasing fibers weight fraction. The similar results were found that the flexural strength and impact strength also increased with increasing fibers weight fraction in the composites.

Keywords: *Polymer composite, Rice straw fiber, Mechanical performance*

INTRODUCTION

Now a days, wide variety of agricultural byproducts have been investigated for the reinforcement of the composites. These include jute, wood, rice husk, rice straw, wheat straw, banana fiber, sisal, bamboo, coir, hemp, flax, and ramie [1-5]. Every year billion of tons of agricultural crop residues are produced around the world but only a small quantity of them are utilized. Most of this residues are burnt in the field and this supply carbon di-oxide in the air and propagate air pollution. By utilizing agricultural crop residues as reinforcement of polymer composites can solve this problem.

Recently rice straw fibers are considered as an alternative to synthetic fibers for use in various fields such as building and construction, packaging, automobile and railway coach interiors and storage devices, and various load bearing applications, door panel, various insulating board, drawing board white board, furniture, decorating fitments, vehicles and shipping manufacturing, packaging and logistics, flooring, acoustic board, hanging board and various application [2-3]. Application of rice straw fibers as reinforcing agent to composites obtained much interests because of increasing environmental awareness and

consciousness throughout the world. They are environmentally friendly, biodegradable, widely available, renewable, cheap, and have low density. Plant fibers are light in weight compared to glass, carbon, and aramid fibers. The attraction in utilizing natural fiber, for example, distinctive wood fiber and plant fiber as support in plastics has expanded drastically throughout last few years. Concerning the ecological viewpoints if natural fibers might be utilized rather than glass fibers as fortification in some structural provisions it might be extremely intriguing.

Ismail Ali et al. [4] conclude that, the water absorption and thickness swelling percentages of rice straw/polyvinyl alcohol increase with increasing the poly vinyl alcohol content in the mix composite, while it behaves in opposite direction for rice straw fiber/polystyrene composite. It was observed that physico-mechanical properties of both composites improved with electron beam irradiation treatment. Ratna Prasad et al. [5] conclude that, the rice straw fiber considerably improve the tensile strength, stiffness, and toughness to a great extent of the resin alone and reduce its density with the increase in percentage volume of fiber in the composite. As the rice straw acts as a

cost reducing agent the composite can be regarded as a successful material in its own right, particularly as a light weight building material.

Rafiquzzaman et.al [6] investigated the mechanical performance of jute-glass fiber based polymer composite. Results indicated that jute fiber can be a very potential candidate in making of composites, especially for partial replacement of high-cost glass fibers for low load bearing applications. AlirezaAshori et al. [7] investigate that, the effect of coupling agent on the mechanical behavior of composites with different fibers was investigated. The coupling agent used offered improved tensile and flexural strength properties relative to the composites without coupling agent and is attributed to the improvement in fiber matrix adhesion in the presence of coupling agent. Previous work by the two lead authors of this paper have reported an improvement in the performance of rice straw as precursor for production of lignocellulosic composites of particle-board type, active carbons for aqueous and gasses purifications, cemented fiber-board and for production of hydrogels in agronomic applications [8-9].

On the subject of utilizing lignocellulosic waste in the production of building elements, in the past decade natural fiber polymer composite (NFPC) from wood waste with thermoplastic and thermoset matrices have been embraced by European car manufacturer and suppliers for door panels, seat backs, head liners, package trays and dash boards. The use of NFPC is due to its advantages over pressure treated lumber, e.g., their low cost, low density, biodegradability, renewability and abundance [10]. Furthermore, Compared to glass fiber and carbon fibers, natural fibers provide many advantages, such as, abundance and low cost, biodegradability, flexibility during processing and less resulting machine wear, minimal health hazards, low density, desirable fiber aspect ratio, and relatively high tensile and flexural modulus.

Incorporating the tough and light-weight natural fibers into polymer matrices produces composites with a high specific stiffness and strength [11]. Rice straw could be used with the current heat and power technologies in many rice producing countries to replace fossil fuels to reduce sulfur dioxide and greenhouse emission as well as prevent pollution from rice straw open burning. Determination of its physical and chemical properties is

required before the utilization as biomass energy to reduce the associated costs of transport, handling and storage which is a major hurdle with respect to its chemical and energy production [12-13]. Hence, with this background, it is concluded that, the natural fiber based composites stand the most wanted technology in the fast growing current trend. In this research work is intended to exploit the advantages of using natural fibers as reinforcement material in composites. Therefore, in this study, an attempt has been made to fabricate rice straw fiber based polymer composite and evaluation its mechanical performances. The work provides basic understanding of the behavior and response of new natural fibers and lightweight materials.

MATERIALS AND METHODS

Materials

In this study, rice straw fiber was used as reinforcement, and the epoxy resin (ADR 246 TX) was used as the matrix shown in the figure 1. Hardener ADH 160 and Methyl Ethyl Ketone Peroxide (MEPOXE) were used to improve the interfacial adhesion and impart strength to the composites. The rice straw fiber was collected from Agricultural Technical Institute farm-Khulna, Bangladesh and the hardener and resin were procured from a hardware store named M/S Color Co. The rice straw having an average length of 150 mm, width of 20mm and thickness of 9mm. A resin and hardener mixture of 3:2 was used to obtain optimum matrix composition. Mechanical properties of rice straw fiber and epoxy resin are shown in Table 1.



Figure 1 Epoxy resin and Rice straw fiber

Table 1. Mechanical Properties of fiber and matrix

Properties	Rice Straw fiber	Epoxy resin
Density (g/cm ³)	0.95	1.2
Young modulus (GPa)	65	2.7
Specific Gravity (gm/cc)	2.2	—
Poisson's ratio	0.2	0.4

Fabrication Procedure

There are many techniques available in industries for manufacturing of composites such as compression molding, injection molding, casting, heat treatment, vacuum molding and resin transfer molding and so on. Among these various methods, hand lay-up process of manufacturing is one of the simplest and easiest methods for manufacturing polyester composites. The primary significance of the hand lay-up technique is to fabricate very large, complex parts with reduced manufacturing times.

Additional benefits are simple equipment and tooling that are relatively less expensive than other manufacturing processes. For this purpose, in this study, the composites were manufactured by the hand lay-up process. To fabricate this polymer composite firstly- the rice straw fiber was collected from Khulna Agriculture farm residue. These fibers wastes was washed with fresh water to remove soil and dust, and then dried at 50 degree Celsius. Dried rice straw fiber then

cut into small pieces about 20 mm long in size. After that make a patterns for making the mold of rice straw fiber polymer composite. Hence, epoxy resin and hardener take in a bowl and mix them properly to make a matrix. Then the rice straw fiber pieces were saturated with epoxy resin and hardener matrix.

Hence, the saturated mixture of rice straw were put on the mold pattern and then rolling them equally by a hand roller. The composite laminate samples were cured by exposure to normal atmospheric conditions. Finally this mold is taken to the simple press to force the air gap to remove any excess air present in between the fibers and resin, and then kept for several (72 hours) hours to get the perfect samples. After the composite material get hardened completely, the composite material is taken out from the mold and rough edges are neatly cut and removed as per the required dimensions. The composite laminate samples were cured by exposure to normal atmospheric conditions.

The fabricated composites were cut using a grinding machine to obtain the specimen for mechanical testing as per the ASTM D3039 standards. The complete sequential fabrication process is shown in Fig. 2.



Figure 2. The complete sequential of fabrication process

Experimental Procedure

The tensile test of the specimen was performed using an electro-mechanical testing machine equipped with the maximum capacity of the load cell at 3 kN. The strength was calculated from the maximum load at failure of the tensile stress. Flexural testing commonly known as three-point bending testing was also carried out as per ASTM D790. Composite specimens of dimensions $120 \times 20 \times 4$ mm were horizontally placed on two supports and load was applied at the center. The deflection was measured by the gauge

placed under the specimen, at the center. Impact testing of the specimen was carried out on Tinius Olsen machine as per procedure mentioned in ASTM D256. Composite specimens were placed in vertical position (Izod Test) and hammer was released to make impact on specimen and CRT reader gives the reading of impact strength. The Rockwell hardness test was performed using a hardness testing machine. All experimental tests were repeated four times to generate the data. Tensile, bending and Impact testing machine are shown in figure 3.



(a)

Fig. 3. (a) UTM machine for tensile and bending test



(b)

Fig. 3. (b) Impact Machine

EXPERIMENTAL RESULTS AND DISCUSSIONS

Tensile Test

The different composite specimen samples are tested in the universal testing machine (UTM) and the samples are left to break till the ultimate tensile strength occurs. The rice straw fiber reinforced composite samples exhibit a significant difference in strength. Experimental results of tensile of various composites with different weight fractions of reinforcement are presented in Table 2 and the comparison results are presented in Figure 6. The results show that, tensile strength of the composites increased with increasing in percentage of fiber weight fraction, and presented the highest average value of 36.87 MPa at fiber weight fraction 40%, and the lowest of 21.23 MPa at fiber weight fraction 10%. When fiber loading is increased the

interfacial bonding also increased and good interfacial bonding between fiber and matrix gives the better tensile strength.

The similar results found in another research work [14], in where composites of rice husk /epoxy showed that there is a linear relationship between the tensile strength and fiber loading. Another study [2] reported that the tensile strength of the rice straw composites increased with increasing in percentage of fiber weight fraction, and average value of 41.40 MPa at fiber weight fraction 40%. Meanwhile in this study the tensile strength was obtained between 25.32 - 36.87 MPa at fiber weight fraction 20 - 40%. The maximum stress of the composite depends on several factors, one such factor is the weight or volume fraction of the fiber.

Table 2: Experimental results of tensile, flexural and impact test for various composites

No. of Experiment	Fiber Weight %	Tensile Strength (M Pa)	Flexural strength (M Pa)	Impact Strength (KJ/m ²)
01	10	21.20	61.45	113.13
02	20	25.32	70.65	126.23
03	30	29.43	82.40	147.33
04	40	36.87	83.81	178.34

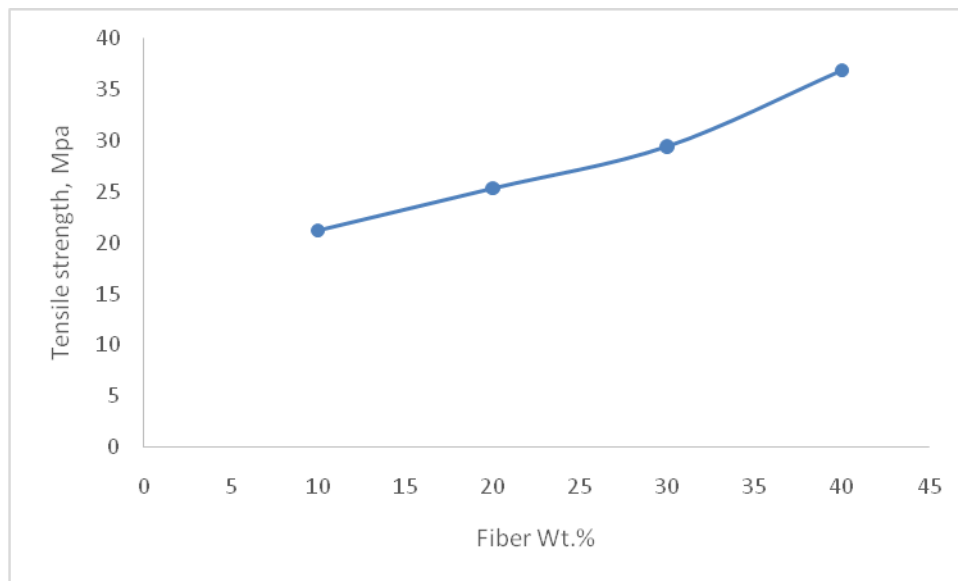


Figure 4. Tensile strength of different sample with different fiber wt. %

Flexural Test

Therice straw fiber reinforced composite samples exhibit a significant difference in bending strength. Flexural results of various composites with different volume fractions of reinforcement are presented in Table 2 and the comparison results are presented in Figure 5.

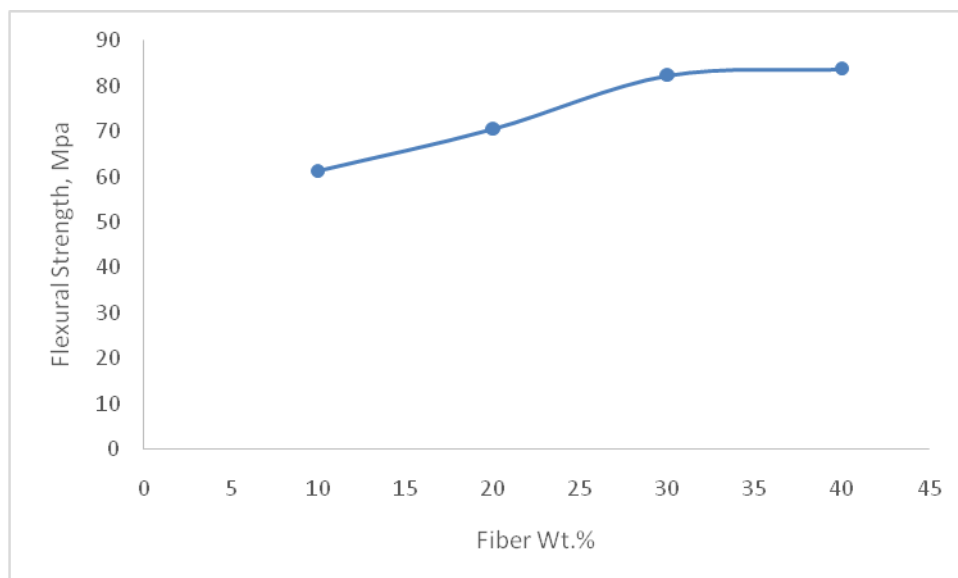


Figure 5. Flexural strength of different sample with different fiber wt. %

The results show that, flexural strength of the composites increased with increasing in percentage of fiber weight fraction, and presented the highest average value of 83.81MPa at fiber weight fraction 40%, and the lowest of 61.45MPa at fiber weight fraction 10%. Another study also [2] reported that the flexural strength of the rice straw composites increased with increasing in percentage of fiber weight fraction. When fiber loading is increased the interfacial bonding also increased and good interfacial bonding between fiber and matrix gives the better flexural strength.

Impact strength:

For analyzing the impact capability of the different specimens an impact test is carried out by Charpy impact test. The energy loss is found out on the reading obtained from the Charpy impact machine.

Experimental results of impact testing of various composites with different weight fractions of reinforcement are presented in Table 2 and the comparison results are presented in Figure 6.

The results show that, flexural strength of the composites increased with increasing in percentage of fiber weight fraction, and presented the highest average value of 178.34KJ/m² at fiber weight fraction 40%, and the lowest of 113.13KJ/m² at fiber weight fraction 10%. Another study also [14] reported that the impact strength of the rice husk composites increased with increasing in percentage of fiber weight fraction. When fiber loading is increased the interfacial area also increased and good interfacial bonding between fiber and matrix gives the better impact strength.

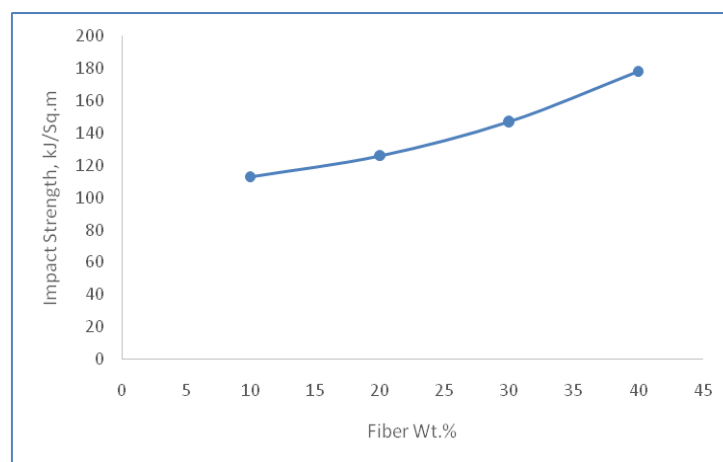


Figure 6. Impact strength of different sample with different fiber wt. %

CONCLUSIONS

Mechanical properties of agricultural byproducts such as rice straw fiber reinforced polymer composites have been observed. The tensile strength of the rice straws composites increased with increasing fibers weight fraction. The similar results were found that the flexural strength and impact strength also increased with increasing fibers weight fraction in the composites. Mechanical properties of rice husks fiber composites were affected by fiber fraction. Engineers and designers can use these data and designed agricultural byproducts composite materials for different applications.

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