Study on Physio-Mechanical Properties of Rice Husk Ash Polyester Resin Composite

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ABSTRACT The rice husk ash/polyester resin composites were prepared by compression molding method and their physical and mechanical properties were studied by universal testing machine. The hardness of the composites were tested by Leeb rebound hardness tester and Vickers hardness tester. The bulk density of the rice husk ash/polyester resin composite decreased with the addition of the rice husk ash, and the water absorption also found to be increased with increase in soaking time. Flexure strength of the composite was decreased randomly with an increase in rice husk ash content. The elastic modulus for the flexure strength increased up to the percentage 0-10% but decreased on 15% and 20% of the rice husk ash/polyester composite. The compressive strength of the composites was decreased randomly with the addition of rice husk ash content, and the elastic modulus for compressive test was increased firstly on the addition of rice husk ash, but it was decreased after 5%. The Hardness of the prepared composite was found to be decreased with an increase of the addition of rice husk ash content due to elastic deformation.

1. INTRODUCTION

Composites, the wonder material with light-weight; high strength-to-weight ratio and stiffness properties have come a long way in replacing the conventional materials like metals, wood etc. A unique feature of composites is that the characteristics of the finished product can be tailored to a specific engineering requirement by the careful selection of matrix and the reinforcement type. For examples aircraft engineers are increasingly searching for structural materials that have low densities, are strong, abrasion and impact resistant, and are not easily corroded. Frequently, strong materials are relatively dense, also increasing the strength or stiffness generally result in a decrease in impact strength [1-4]. Nature is full of examples wherein the idea of composite materials is used. The coconut palm leaf, for example, is nothing but a cantilever using the concept of fiber reinforcement. Wood is a fibrous composite; cellulose fibers in a lignin matrix. The cellulose fibers have high tensile strength but are very flexible (i.e. low stiffness), while the lignin matrix joins the fibers and furnishes the stiffness. Bone is yet another example of a natural composite that supports the weight of various members of the body [5-7]. Composites are combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and are embedded in the other materials called the matrix phase. The reinforcing materials and the matrix material can be metal, ceramic, or polymer. Typically reinforcing materials are strong with low densities while the matrix is usually a ductile, or tough, material [8-10]. If the composite is designed and fabricated correctly, it combines the strength of the reinforcement with toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material. Examples of some current application of composites include the brake-shoes, submarine,
satellite, civil infrastructures, pads, tires and the diesel piston aircraft in which 100% of the structural components are composites [11]. Recently many types of natural fibers have been investigated for use in plastics including rice husk, jute, straw, wood, wheat, barley, oats, rye, bamboo, sugarcane, grass, reeds, ramie, sisal, coir, banana, papyrus etc. Natural fiber have many significant advantages over synthetic fiber. The primary advantage of natural lignocellulose fiber reinforcement in polymer composite materials is its biodegradable, abundantly available, easily decomposable in the environment and eco-friendly [12].

Polymeric science and technology is one of the most active and promising fields in science, embracing a multitude of topics natural polymers such as cellulose, wool, jute, palm fiber etc which are of outmost importance for living systems, to synthetic high polymers. The polymer materials that are biodegradable now enjoying considerable popularity, especially from the standpoint of environmental protection [13]. In recent years, many research works were developed in the field of natural fiber reinforced composites for using in several applications [14]. Natural fibers having low density, availability, high toughness, acceptable specific strength, enhance energy recovery, low cost and biodegradability are used as reinforcements in the polymer matrix. A large abundance of natural fibers like jute, coir, sisal, flax, pineapple leaf fiber, hemp, kenaf, banana and so forth has enhanced the interest of researchers because of increasing environmental consciousness [15-18]. The intention of this research work is to achieve a composite with high mechanical properties using rice husk ash fiber as reinforcement with polyester resin as a polymer matrix.

M. Ashok Kumar et al. [19] have studied the utilisation of CF/Sawdust reinforced Epoxy hybrid composites on mechanical properties and found that the hybridisation of carbon fiber and saw dust was in similar to EP/CF hybrid composites. Humayun et al investigated the physical and mechanical properties of bamboo fiber and PVC foam sheet composites. They observed that tensile strength, flexural stress, flexural strain and tangent modulus of the composites increased while the tensile strain decreased with the subsequent fiber addition to the PVC sheets [20]. Ofem et al. [21] studied the mechanical properties of rice husk filled cashew nut shell liquid resin composites and showed that both filler loading and particle size can affect the tensile strength, young modulus, strain at failure, flexural strength, and impact strength. Rice husk flour filled polypropylene composite were prepared by Yang et al. [22] and found that tensile strengths of the composites slightly decreased as the filler loading increased. Comparison of the mechanical properties of the rice husk powder filled polypropylene composites with talc filled polypropylene composites have been studied by Premalal et al. [23]. Young’s modulus and flexural modulus increased whereas yield strength and elongation at break decreased with the increase in filled loading for both types of composite.

In the present study, our attention has been given on the improvement of physical and mechanical properties of rice husk ash/polyester resin composites with increase in wt% of rice husk ash and length of soaking time.

2. MATERIALS AND METHODS

2.1 PREPARATION OF COMPOSITE

Raw materials that have been used in this research work were polyester resin, rice husk ash and Methyl ethyl ketone per oxide as hardener. Different percentage of rice husk ash and polyester resin were taken to prepare composite. Rice husk ash was taken from 0 to 20 wt %. The table-1 shows different percentages of samples. A bowl was taken to mix up the raw materials of the composite. Definite amount of various percentages of rice husk ash & polyester resin has been weighed in the bowl and then raw materials were mixed very carefully with a stirrer for about 15 Minutes. Ethyl methyl ketone peroxide was used as a hardener, as an amount of 2 wt% of polyester resin and weight. The mixer was then poured into the closed and open mold and was kept it 4-5 hours for drying. After drying the composite was released from the mold with Paul-Otto Weber
Press Machine by applying pressure. Polyethylene sheet was used to smoothen the sides of the composite.

Table 1: Rice husk ash/polyester composite

<table>
<thead>
<tr>
<th>Composite</th>
<th>Rice husk ash (%)</th>
<th>Polyester resin (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APC-1</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>APC-2</td>
<td>5</td>
<td>95</td>
</tr>
<tr>
<td>APC-3</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>APC-4</td>
<td>15</td>
<td>85</td>
</tr>
<tr>
<td>APC-5</td>
<td>20</td>
<td>80</td>
</tr>
</tbody>
</table>

2.2 CHARACTERIZATION OF PREPARED COMPOSITE

The bulk density of the composite was determined according to ASTM C134-76 (Standard Test Method for Size, Dimensional Measurements, and Bulk Density of Refractory Bricks) by measuring the weight and dimensions of the respective composite samples using the following relation.

\[ D = \frac{W_t}{L \times W \times H} \]  \hspace{1cm} (1)

where \( W_t, L, W \) and \( H \) are the weight, length, width and height of the composites respectively [24]. Prior to measuring the density (and carrying out the other tests), the samples were conditioned at 50 °C for 24 h placing them into the incubator. Average densities were obtained using results from three specimens of each batch.

The water absorption test of the composites was carried out according to ASTM D570-98 (Standard Test Method for Water Absorption of Plastics) with repeated immersions in distilled water at room temperature (about 25 °C) [25]. The test specimens were in the form of rectangular bars 76.2 mm long by 25.4 mm wide by the thickness of the material. It was measured by soaking the samples in five glass beaker (for 0%, 5%, 10%, 15% and 20%) of water at 25°C for different periods (upto 576 hours). The weight of the samples was measured before immersion of the sample. After certain period of times, samples were taken out from the water, wiped using tissue papers and then measured weight. The water uptake (mass gained) was measured by subtraction of initial weight from final weight. The percentage of water absorption was determined by using the formula [26].

\[ W_a = \frac{W_a-W_0}{W_0} \times 100 \]  \hspace{1cm} (2)

Where \( W_a \) and \( W_0 \) are the weight of the sample after and before soaking in water.

The tensile and flexural tests were performed with a Universal Testing Machine (UTM) (Hounsfield II10KS, England) using a 10 kN load cell and were monitored with a computer through QMat Professional (Tinius Olsen, UK) software. The tensile test of the composites was performed according to ASTM D3039/D3039M-00 (Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials) maintaining the length of the specimen between the tips of the UTM's jaws to 80mm (i.e., the gage length) [27]. The specimens were in the form of rectangular bars 15 mm by 127 mm by thickness. The test was carried out to failure at cross-head speed of 2 mm/min. The flexural tests (3-point bending) were carried out according to ASTM D790-00 (Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials) [28]. Average was obtained from the results often specimens for each batch.

The Leeb hardness test of the composites was carried out with an H1000 portable hardness tester (HARTIP-1000, QUALITEST, Canada) according to ASTM A956-06 (Standard Test Method for Leeb Hardness Testing of Steel Products) [29]. The hardness was measured at 40-50 different
locations over both of the sample surfaces. Average data was considered as the Leeb hardness of the sample.

3. RESULTS AND DISCUSSION

3.1 PHYSICAL PROPERTIES

3.1.1 Bulk Density

Fig-1 shows the variation of bulk density of rice husk ash polyester (RHA-PS) composites with rice husk ash contents.

![Graph showing Variation of Bulk Density](image)

Fig. 1. Effect of amount of RHA on density of RHA-PS composite.

In fig-1, it is observed that the density of RHA-PS composites increased a little first then it decreased with further addition of RHA. This is expected because the density of RHA is smaller than that of polyester [20]. The decrease in density of the composites with increase in fiber content was also found by several researchers [30].

3.1.2 Water Absorption

The effect of immersion time on water absorption of RHA-PS composites prepared with different wt% (0%, 5%, 10%, 15% and 20%) of RHA is shown in Fig. 2. It reveals that the water absorption depend on RHA content and immersion of time for all composites. Result shows that the water absorption increased with increasing RHA [20]. It is evident that percentage of water absorption is higher for 15% RHA and lower for 0% RHA composites [30]. The rate of water absorption is very low with time. This is due to the fact that reduction in the cured polyester and the degree of cross-linking reaction, which diminishes the void spaces i.e. with the increase of molding load, the composite becomes more dense or reinforced materials are distributed properly eliminating all voids. Mineral fillers are hydrophobic in nature (the incapability of filler to absorb water is known to be hydrophobic filler). This is because of hydrophobic nature of RHA is very small amount of water intake in the composites [31, 32].
3.2 MECHANICAL PROPERTIES

3.2.1 Flexural Strength

Flexural strength is also known as bending strength or rapture strength. The flexural strength of a material is defined as its ability to resist deformation under load. Flexural specimen was prepared according to ASTM D790M, 3 point loading [33]. The strength may be calculated for any point of the load deflection by means of the following equation,

$$ S = \frac{3PL}{2BD^2} $$

Where, $S$ = stress in the outer fibers at mid-span, MPa, $P$ = load at a given point on the load – deflection curve, N, $L$ = support span, mm, $B$ = width of specimen tested, mm, $D$ = depth of tested specimen, mm.

Fig. 3 illustrates the effect of addition of RHA on flexural strength for RHA-PS composite. It reveals that the flexural strength decreases with the addition of RHA content. The flexural strength of the composites is lower than polyester resins, so these composites are brittle. Ceramic materials are brittle, hard, and strong in compression, weak in shearing and tension. It shows that the increasing in volume fraction of RHA promotes more interfaces and cavities formed in the composite and this can explain the decreasing of flexural strength. The decrease in strength of RHA polyester composites on increasing the volume fraction of RHA is due to RHA being weak in tension.
3.2.2 Elastic Modulus

Elastic (E) Modulus of RHA-PS composites as a function of the addition of different RHA percentage are shown in Fig. 4. It is found that the E-Modulus of the composite increased with an increase in RHA content. For more addition of RHA, E-Modulus decreased. The E-Modulus is a measure of stiffness of a material. Thus, the stiffness of RHA-PS composite increased with an increase in RHA addition until 5% and then decreases with more addition of RHA. Finally it increased for 20% RHA content.

3.2.3 Compressive Strength

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. When the limit of compressive strength is reached, materials are crushed. The compressive strength is usually obtained experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. The effect of addition of RHA on compressive strength of RHA-PS composite is represented in Fig. 5. It is seen from Fig. 5 that compressive strength of RHA-PS composite decreases with the increase of rice husk ash [34]. Variation of compressive strength of RHA-PS composites depends on the size of particles.
Fig. 4. Effect of variation of RHA on Elastic modulus of RHA-PS composite.

Fig. 5. Effect of variation of RHA on compressive strength of RHA-PS composite.

3.2.4 Vickers Hardness

The Vickers hardness (HV) is calculated with an equation, wherein load (L) is in grams force and the mean of two diagonals (d) is in millimeters [35]:

\[
HV = 1854.4 \times \frac{L}{d^2}
\]

For this measurement, appropriate size of a sample with flat and smooth surface was preferred. During measurements, at least 8 imprints were taken for each load, and the \( H \)-values for all samples were determined with standard errors.
Fig. 6. Effect of variation of RHA on Vickers Hardness of RHA-PS composite.

Fig. 6 illustrates that Vickers Hardness for RHA-PS composite as a function of the addition of different wt% of RHA. It can be seen that in this composites, Hardness decreased with an increase of RHA. It represents that RHA-PS composite is softer than pure sample of the polyester composite.

3.2.5 Leeb Rebound Hardness

Leeb rebound hardness measures the hardness of sample material and harden material produce a higher rebound velocity than softer material.

Fig. 7. Effect of addition of RHA on Rebound Hardness of RHA-PS composite.

Fig. 7 presents the effect of addition of RHA on rebound hardness of RHA-PS composite. The obtained results indicated that rebound hardness of RHA-PS composite decreased with the increase of RHA content. As the stiffness of the polyester is high and that of for RHA is lower, hence RHA-PS composites is softer than pure polyester composites.
4. CONCLUSION
The bulk density of rice husk ash/Polyester composites decreased very slowly with an increase in the amount of rice husk ash content. For all the composites water absorption increases with increase of fiber addition and soaking time. Flexural strength of rice husk ash/Polyester composites decreased constantly with an increase of rice husk ash content. But the modulus of rice husk ash/composite increase with the addition of rice husk ash constantly and after 15% modulus suddenly decreases. The flexural strength was lower than polyester resin, so these composites are more brittle. The compressive strength was decreased with an increase the amount of rice husk ash and it was found that E-modulus increased at the beginning of the addition of rice husk ash but it was suddenly decreased on the addition of 10% and 15% of rice husk ash. Hardness of the composite decreased with an increase in the addition of rice husk ash content due to elastic deformation.

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