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Evaluation of Mechanical Properties of Rice Husk-Fly Ash-Epoxy Hybrid Composites

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Abstract: *An attempt has been made in this investigation to develop natural fibers reinforced polymer composites using rice husk and fly ash as reinforcements. The content of rice husk is varied (10, 15 and 20 weight percentages) whereas the fly ash percentage is kept constant at 5 % in epoxy matrix. Composites have been fabricated using hand layup technique using a suitable die developed in house. All the samples have been tested in Universal Testing Machine as per standard for tensile strength and flexural strength. The hardness and water absorption tests were also carried out. It is observed that composite with 10% rice husk is having highest tensile strength of 33 MPa. Similarly the flexure modulus for 10 % rice husk composite was 4881 MPa. The impact strength of composite with 20 % rice husk was highest. The hardness test showed that composite of 20% rice husk was highest. The water absorption test reveals that composite with 10 % rice husk is the best. It is recommended that composite with 10% rice husk and 5 % fly ash with epoxy matrix will be suitable for structural applications. The composite with 15 or 20 % rice husk may not be used for such purposes. Composite with 15 and 20 % rice husk may be used for making parts of automobiles. But these will not be suitable to work in moist environment. However composite with 10 % rice husk will be suitable for structural applications like packaging, interior decorations, body of washing machines and domestic appliances etc.*

Keywords*: Rice Husk-Fly Ash-Epoxy Hybrid Composites, tensile, hardness, flexure, impact, water absorption tests*

I. Introduction

Lot of research is going on in the field of material science to develop environment friendly material due to increasing concern about environment and depleting conventional materials. Under circumstances natural fibers and bio waste have become interesting materials to be used as reinforcement in polymer matrix to develop green composites. Application of high-performance composites using natural fibers is increasing in various engineering fields. Composite materials comprising one or more phase(s) belonging to natural or biological origin are called green or bio-composite. During the last decade there has been a renewed interest in the natural fibres as substitute for glass , motivated by potential advantage of weight saving, lower raw material price, and thermal recycling or the ecological advantages of using resources which are renewable. The composites produced today with the incorporation of natural fibres as reinforcements in polymeric matrix are used for boat hulls, surfboards, sporting goods, swimming pool linings, building panels and car bodies. This not only reduces the cost but also save from environmental pollution and waste otherwise thrown in the open. These composites are also used in panels for partition and false ceiling, partition boards, wall, floor, window and door frames, roof tiles, mobile or pre-fabricated buildings which can be used in times of natural calamities such as floods, cyclones, earthquakes, etc. Keeping this in view it has been thought proper to develop hybrid composites of rice husk, fly ash and epoxy where the fly ash content is kept constant and rice husk percentage is varied as reinforcements..

II. Literature Review

An attempt has been made here to know the direction of research in the field of natural fibre reinforced polymer composites using fly ash and rice husk as reinforcements. Therefore review of literature has been carried out over last decade. Saxena et al. [1] investigated industrial waste reinforced polymer composites as a potential wood substitute material. Plant fiber along with industrial waste (fly ash and red mud) were used for synthesizing the composite materials. Properties such as physical and mechanical, resistance to abrasive wear, weathering and fire etc. were studied. It was observed that polymer—natural fiber—industrial (inorganic) waste composites attain far superior mechanical properties and resistance to abrasive wear, fire, water absorption, weathering, and chemical attack, as compared to their conventional counterparts such as wood, medium density fibre (MDF) boards, particle board, etc. Harish et al. [2] evaluated the mechanical properties of natural fibre coir composites. Coir instead of artificial fibre such as glass, carbon etc. was used to develop composites and each fibre was about 0.01 to 0.04 in. (0.03 to 0.1 cm) long and 12 to 24 μm in diameter. Composites were prepared by hand layup technique with matrix as epoxy. After testing it was found that the tensile strength, flexural strength and impact strength of composites have substantially increased. Singla and Chawla [3] investigated the mechanical strength of epoxy resin fly ash composite. Composite preparation was done by taking different weight percentage of fly ash and resin. Material was subjected to compression and impact test by taking different weight percentage of fly ash. It was observed that the compressive strength of the composite increased with increase of fly ash percentage. The effect of particle size and volume fraction on tensile properties of flyash/polyurea composites was carried out by Qiao et al.[4]. A one-step method was chosen to fabricate pure polyurea and the polyurea matrix for the composites based on Isonate 2143L (diisocyanate) and Versalink P-1000 (diamine). Scanning electron microscopy was used to observe the fracture surfaces of the composites. The tensile properties of the pure polyurea and fly ash/polyurea (FA/PU) composites were tested using an Instron load frame with a 1 kN Interface model 1500ASK-200 load cell. Results showed that fly ash particles were distributed homogeneously in the polyurea matrix and all of the composites displayed rubber-like tensile behavior similar to that of pure polyurea. The tensile strength of the composites was influenced by both the fly ash size and the volume fraction. Compared to the largest particle size or the highest volume fraction, an increase in tensile strength was achieved by reducing particle size and/or volume fraction. The strain at break of the composites also increased by using fine particles. Sayfri et al.[5]investigated effect of rice husk surface modification by LENR(Liquid Epoxidized Natural Rubber) the on mechanical properties of nr/hdpe reinforced rice husk composite. Surface modification of rice husk (RH) with alkali pre-treatment (NaOH solution 5% w/v) was carried out at the initial state to investigate the effect of surface treatment of fibre on the surface interaction between fibre and rubber. Further modification of RH surfaces after alkali treatment was using LENR coating at three concentrations, 5%, 10%, and 20% wt LENR solution in toluene. It was found that 10% wt LENR solution gave the optimum interaction between fibre and rubber. Result showed that pre-treatment of RH treated with 5% NaOH followed by treatment with 10% LENR solution given the maximum interaction between fibre and matrix that gave rise to better mechanical properties of the composites. Rout and Satapathy [6] studied the mechanical and tribo-performance of rice-husk filled glass–epoxy hybrid composites. The results indicate that impact velocity, filler content, impingement angle and erodent size influence the wear rate significantly. This study reveals that hardness, tensile modulus, impact energy and erosion resistance of these new class hybrid composites are improving with filler addition while a steady decline in tensile and flexural properties are observed. Shubham and Tiwari [7] investigated effect of fly ash concentration and surface modification of fiber reinforced epoxy composite. It was shown that damping capability and thermal stability were improved with low concentration of fly ash. .It was observed that silanization of fly ash had improved the tensile strength and toughness. SEM analysis showed that surface modification of fly ash with coupling agent enhanced their bonding with polymer resin which resulted in lower damping capability and improved strength and toughness. Raghavendra et al. [8] investigated mechanical properties of fly ash filler in natural fiber- hybrid epoxy composites. The laminates of 4 piles were prepared by using hand lay-up technique.. One group of glass laminate was also fabricated for comparison purpose. Specimen preparation and testing was carried out as per ASTM standards. Due to incorporation of fly ash fillers in to the jute composites there is 10 % of strength increment in tensile and 20 % in flexural. He found that by incorporation of bio and industrial waste in to the polymer material the mechanical properties almost enhanced to a greater extent.The 10% fly ash filler reinforced composites give almost 55% of the glass fiber composite strength. Arpitha et al. [9] considered epoxy, Sisal fiber, glass fiber, silicon carbide as filler materials in polymer respectively to make composites. Experiments were conducted by varying weight fractions of SiC (3,6,9%) while keeping all other parameters constant. It was observed that Sisal/Glass composite samples possess good tensile strength and impact strength. It was also found that sisal/glass with 3% of silicon carbide filler shows good flexural strength compared to other composites. Islam et al.[10] studied physio-mechanical properties of rice husk ash polyester resin composite. The rice husk ash/polyester resin composites were prepared by compression molding method and their physical and mechanical properties were studied. it was observed that the bulk density of rice husk ash/polyester composites decreased very slowly with an increase in the amount of rice husk ash content. Vishnu and Manavendra [11] investigated the thermal properties of fly ash reinforced epoxy composite. The investigation has focused on the maximum utilization of abundantly available industrial waste fly ash in a useful manner. The thermal properties of the composites like Thermal conductivity, Specific heat capacity, Linear coefficient of Thermal expansion and Thermal diffusivity were experimentally determined in the engineering laboratory.It was observed that the incorporation of fly ash particles results in decrease in the thermal conductivity compared to that of pure epoxy thereby improves its thermal insulation capability and exhibit higher specific heat carrying capacity than composite without fly ash because higher fly ash content in composite higher will be the heat carrying capacity of the composite. Mishra [12] investigated the mechanical characteristics of chicken feather-teak wood dust filled epoxy composites. Composites of teak wood dust (450 μm size) in 10,15 and 20 percentages of weight mixed with epoxy along with 5 % of chopped chicken feather have been prepared by hand lay up technique. The tensile strength was tested by universal testing machine. The water absorption tests in 24 hours was done. The results show the gain in weight is very little and negligible for all the composites So the composites can perform very well in moist atmosphere.

III. Scope

The following objectives have been set for the present investigation.

1. To develop hybrid composites of rice husk, fly ash and epoxy composites by varying the percentages of rice husk.
2. Fly ash content is kept constant at 5% of the weight and rice husk at 10, 15 and 20 weight percentages.
3. Composite will be prepared by hand layup technique in the form of lamina.
4. Test specimens as per standards will be prepared for tensile, flexural strength, hardness and water absorption tests etc.
5. The results after testing will be analyzed and the best out of the above specimen will be chosen for specific engineering applications.

IV. Theoretical Investigations

The composite is usually prepared based on calculation of weight fractions or volume fractions of matrix or filler material. Since random distribution of filler material has been considered various properties of the composite are found out following rule of mixtures as mentioned below.

Weight fraction of the reinforcement: $w_r = W_r / (W_r + W_m + W_f) * 100$,

Weight fraction of the matrix: $w_m = W_m/(W_r + W_m + W_f)*100$

Weight fraction of the filler: $w_f = W_f/(W_r + W_m + W_f)*100$

Where W_r = Weight of reinforcement (rice husk), W_m = Weight of matrix(epoxy) and W_f=Weight of filler.(Fly ash)

Weight of the composite = $W_c = W_r + W_m + W_f$

Further as per rule of mixtures, the density of the composite is obtained by

$$\rho_c = \rho_m v_m + \rho_r v_r + \rho_f v_f \quad (1)$$

where ρ_c = Density of the composite, ρ_m = Density of the matrix, ρ_r = Density of the reinforcement and ρ_f= Density of the filler

v_m = Volume fraction of the matrix, v_r = Volume fraction of the reinforcement and v_f= Volume fraction of filler.

Here $v_m = V_m / (V_m + V_r + V_f + V_v)*100$, $v_r = V_r / (V_m + V_r + V_f + V_v)*100$ and

Volume of the composite = $V_c = V_m + V_r + V_f + V_v$

Where V_m = Volume of the matrix, V_r = Volume of the reinforcement, V_f= Volume of filler and V_v= Volume of voids (not considered here)

Assuming modulus reinforcing efficiency as unity and as per rule of mixtures: Modulus of elasticity of the composite

$$E_c = E_m v_m + E_r v_r + E_f v_f \quad (2)$$

Where E_r = Modulus of elasticity of reinforcement, E_m = Modulus of elasticity of Matrix and E_f=Moduus of elasticity of filler.

Strength of the composite

$$\sigma_c = \sigma_m v_m + \sigma_r v_r + \sigma_f v_f \quad (3)$$

Where σ_r = strength of the reinforcement, σ_m = Strength of the matrix and σ_f=Strength of Filler.

Properties of individual constituents are given in Table 1,2 and 3.

Table 1 Properties of epoxy

Properties	Value
Density (gm/cc)	1.2
Elastic modulus (GPa)	20
Tensile strength (MPa)	75

Table 2 Properties of rice husk

Properties	Value
Density (gm/cc)	1.0
Elastic modulus (GPa)	5.0
Tensile strength (MPa)	180

Table 3 Properties of fly ash

Properties	Value
Density (gm/cc)	1.53
Elastic modulus (GPa)	2.3
Compressive strength (MPa)	17

Using Eqns 1,2 and 3 the properties of the composites have been found out as in Table 4.

Table.4 Properties of Composite

Composites	Density (gm/cc)	Elastic modulus (GPa)	Tensile strength (MPa)
Specimen – A	1.1965	17.615	80.9
Specimen-B	1.1865	17.115	95.15
Specimen-C	1.1765	16.365	100.4

Specimen –A - 10 % Rice husk composite
Specimen-B - 15 % Rice husk composite
Specimen-C - 20 % rice husk composite

V. Experimental Work

Materials

Fly ash sample used in this study was collected from National Thermal Power Corporation Ltd, Talcher Thermal. (Fig.1). Upon collection, the fly ash was first dehydrated in the oven at 105˚C . The mesh size of the fly ash has been measured in scanning electron microscope and average size was found to be 100 µm (Fig.2).

Fig. 1. Fly Ash sample

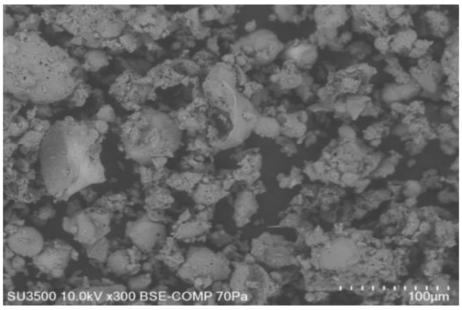


Fig..2. SEM of fly Ash (size- 100 µm)

Fig. 3 Rice husk sample

Rice husk sample (Fig.3) was collected from the rice mill, Sambalpur, Odisha. For removing the moisture content it was dried up in an oven at 100^0 C. The size of rice husk was found to be 426µm measured through a sieve shaker. Epoxy CY230 and Hardner HY951 were collected from Hindustan Ciba Geigy Ltd., Kolkata, India

Composite Preparation

A wooden mould of dimension (100×100×10) $mm^3$was used for casting the composite sheet (Fig.4). The samples were manufactured with different weight fractions of rice husk and fly ash. With different weight fraction of rice husk (10,15 and 20 %) , fly ash (5%-constant) epoxy and hardener was thoroughly mixed with gentle stirring to minimize air entrapment. The epoxy and hardener were mixed in 10:1 ratio. Then by using hand layup technique, the mixture was poured into the mold. For quick and easy removal of composite sheets, mold release agent (silicone spray)was applied at the inner surface of the mould. Care was taken to avoid formation of air bubbles. The mold was allowed to cure at room temperature for24 hrs. After 24 hrs the samples were taken out of the mould (Fig.5 a,b,c), cut into different sizes as per standard for further experimentation.

Fig.4. Wooden mould and cast specimen


(a)

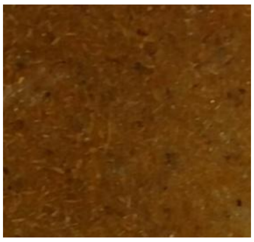
(b)

(c)

Fig. 5 a,b,c. Composite Lamina with 10 %, 15% & 20% rice husk respectively

Test procedures

Tensile test

The coupon test samples for tensile test (Fig.6) are cut from the lamina according to reference standard of ASTM as shown in Fig.6 and actual dimensions are also given in Table 5. The tensile test was done according to ASTM standard (D-638) in Universal Testing Machine, UK make (Fig.7) The specification of the machine is given in Table 6.

Fig..6 Coupon test sample

Table 5.Actual dimensions of the test specimens

Specimen	Length(mm)	Width(mm)	Thickness(mm)
A	200	24	8.2
B	200	24	3
C	200	24	2.5

Fig.7.UTM for tensile test

Table 6 Specification of UTM

Machine Capacity	kN	250
Machine Capacity	tons	25
Maximum Testing Speed	mm/min	300
Minimum Testing Speed	mm/min	0.1
Jog Speed	mm/min	up to 400
Speed Accuracy	mm/min	0.1
Positioning Accuracy	mm	0.01
Horizontal Clearance	mm	600
Crosshead Travel Excluding Grips	mm	1320
Crosshead Travel with Wedge Grips Installed	mm	800
Overall Height	mm	2460
Overall Width	mm	1300
Overall Depth	mm	670
Weight(approx.)	kgs	880

Flexural Modulus test
The flexural modulus test was done according to ASTM standard (D-790) in the same UTM with three point bending.

Impact strength
The Izod impact strength test was done according to ASTM standard (D-256). The machine has benn shown in Fig.8.

Fig. 8 Izod impact test

Water absorption
The water absorption test as per standard ASTM- D570 was conducted. The specimen A was of 50x50x 8 mm and specimen B and C were of 50×50×3mm size (Fig. 8). The test was conducted for 24 hrs and 72 hrs respectively for all the specimens. The dry weight and final weights were measured through an electronic balance of three decimal accuracy to ontain the gain in weight.

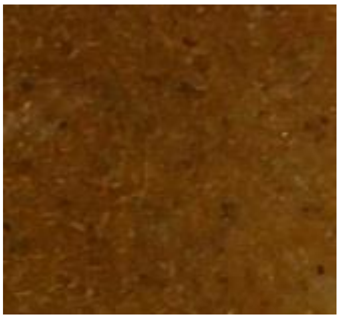


Fig.8. Water absorption test sample

Hardness test
The Rockwell hardness test was done according to ASTM standard (D-785) in a Rockwell Hardness Tester (Fig.9).

Fig. 9 Rockwell hardness tester

VI. Results And Discussion

The results of tensile tests for three different specimens have been plotted in Fig. 10 , 11 and 12 for 10. 15 and 20 % rice husk composites respectively. These results are interpreted in Table 7.

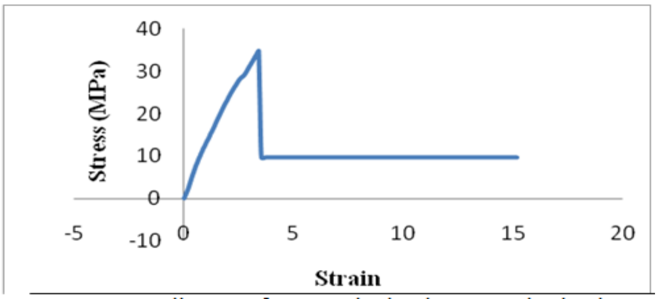


Fig. 10 Tensile test of composite having 10% rice husk

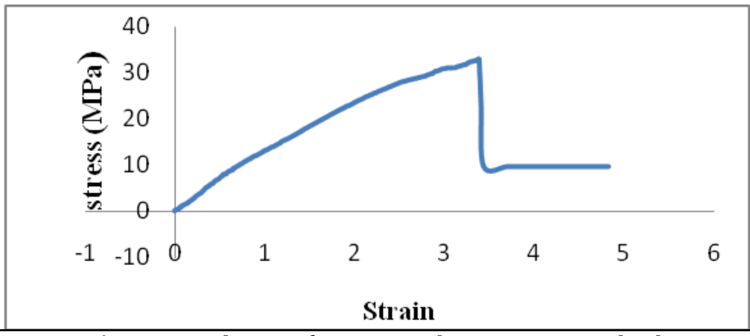


Fig. 11 Tensile test of composite having 15% rice husk

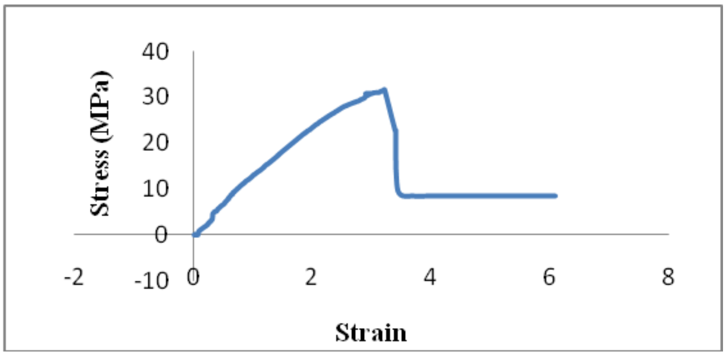


Fig. 12 Tensile test of composite having 20% rice husk

Table 7 Results of tensile test

Specimen	Gage length (mm)	Maximum load (kN)	Tensile strength (MPa)	Breaking(kn/m)	Load at break (kN)	Strength at break(MPa)	Elastic modulus (GPa)
A	85	6.840	35	0.28	1.900	10	1.06
B	86	6.810	33	0.25	1.756	9.5	1.04
C	85	6.650	32	0.22	1.650	9.3	1.00

The plot of flexural stress and flexural strain for three types of composites is indicated in Fig. 12.

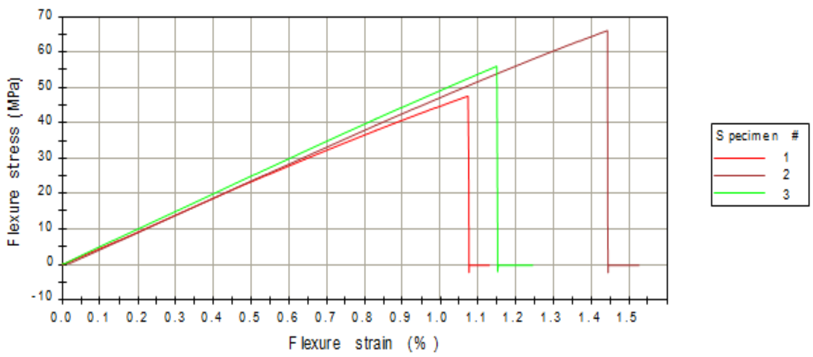


Fig.13. Stress-Strain curve for flexure test

The value of flexural modulus obtained are 4881.75MPa, 2846.70 MPa and 2884.80 MPa for 10,15 and 20 % rice husk composites respectively. The results obtained from impact and hardness tests are indicated in Table 8.

Table 8 Impact strength and hardness

Specimen	Impact strength (J/m)	Hardness (RC)
A	8.91	65.12
B	16.07	60.8
C	20.85	70.2

The water absorption test results after soaking for 24 hrs and 72 hrs are given in Table 9 and 10.

Table 9.Results of water absorption test after 24 hrs soaking

Sl.No	Wt. of dry composite (Kg.)	Wt. of composite after water absorbed (Kg.)	Gain in weight (%)
A	0.040	0.041	2.5
B	0.020	0.022	10
C	0.015	0.017	13.33

Table 10. Water absorption test for 72hrs

SL NO.	Wt. of dry composite (Kg.)	Wt. of composite after water absorbed (Kg.)	Gain in weight (%)
A	0.040	0.042	5
B	0.020	0.023	15
C	0.015	0.018	20

From the results obtained as above it is now observed that the composite having 10 % rice husk is having maximum tensile strength i.e 35 MPa and flexural modulus of 4881.75 MPa. Hardness of this composite is also moderate having 65.12 RC. But for this material the impact strength is low. As far as water absorption capacity is concerned the specimen sample of 10 % rice husk exhibited excellent property and suitable to work in moist environment. However the sample with 20% rice husk is having hardness of 70.2 RC, highest impact strength, low flexural and tensile strengths. This composite may not be recommended for use in aquatic environment. Thus where hardness and impact properties are required the sample C may be used or sample B.

VII. Conclusions

After developing natural fibre reinforced composites prepared out of waste like fly ash and rice husk it is observed that composite with 10% rice husk and 5 % fly ash with epoxy matrix will be suitable for structural applications. The composite with 15 or 20 % rice husk may not be used for such purposes. Now a days the automobile industry is in search of light weight materials to reduce the overall weight of the vehicle. Composite with 15 and 20 % rice husk may be used for making parts of automobiles. But these will not be suitable to work in moist environment. How ever it is recommended that the composite with 10 % rice husk will be suitable for structural applications like packaging, interior decorations, body of washing machines and domestic appliances etc.

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