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Mechanical Properties of Cocconut Shell Dust, Epoxy - Fly Ash Hybrid Composites

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ABSTRACT: *Attempt has been made in this investigation to find put the mechanical behavior and water absorption capacity of coconut shell dust (CSP), Fly ash reinforced epoxy hybrid composites. Fly ash percentage has been kept constant at 5 wt % and the coconut shell dust content is varied from 10,15 and 20 wt %. Fabrication of composite laminates has been done by hand lay up technique with random distribution of reinforcements. The mechanical properties of the composite laminates so prepared have been investigated such as micro structure, tensile strength, hardness, water absorption etc. as per standards. From the tensile test it is observed that as the percentage of coconut shell dust increases the tensile strength of the samples increases up to 15% & then decreases for 20% shell dust reinforced composite. The Vickers hardness test gave the values as 15.884VHN, 16.098VHN and 16.88VHN for 10%, 15% and 20% CSP reinforcement respectively. From the water absorption test as the gain in weight is less than 2% hence moisture absorption is negligible. It is also seen from the micro structure analysis that the shell dust is evenly distributed in the matrix. Because of this even distribution of filler in the epoxy matrix probably the hardness and strength values are quite optimum and the composite can be a promising material for future applications.*

Key words: *Coconut shell dust, fly ash, epoxy composites, Mechanical tests, water absorption etc.*

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I. INTRODUCTION

Over a past few decades composites, plastics, ceramics have been the dominant engineering materials. The areas of applications of composite materials have grown rapidly and have even found new markets. Modern day composite materials consist of many materials in day to day use and also being used in sophisticated applications while composites have already proven their worth as weight saving materials. The current challenge is to make them durable in tough conditions to replace other materials and also to make them cost effective. This has resulted in development of many new techniques currently being used in the industry. The composite industry has begun to recognise the various applications in industry mainly in the transportation sector. In recent years, the continuous and increasing demand for environmentally friendly materials such as bio-composites from plant-derived fibres and from recycled fibre based products has been on the increase due to their potential characteristics. India endowed with an abundant availability of natural fibre such as Jute, Coir, Sisal, Ramie, Bamboo, Banana, Bagasse etc. has focused on the development of natural fibre composites primarily to explore value-added application avenues. While the use of composites is a clear choice in many applications but the selection of materials will depend on the factors such as working life, lifetime requirements, complexity of product shape, number of items to be produced , savings in terms of cost and the experience and skill of designer to trap the optimum skill of the composites.

II. REVIEW OF LITERATURE

Literature review is carried out to get the background information on the issues to be considered in the present research work and to focus the relevance of the present study. The purpose is also to present a thorough understanding of various aspects of fly ash and epoxy composite with varied concentrations of coconut shell dust that can be used as reinforcement in composite with a special attention to their mechanical properties and future applications. The use of composite materials having light weight and high strength in aerospace, automotive, domestic appliances, navigation and rocketry is gaining importance. Under circumstances, utilization of waste for developing such materials having reasonable strength and other mechanical properties finds sincere attention of researchers worldwide. Therefore it has been thought proper to have a review to know the direction of research particularly use of natural fibres for composite preparation. Their utility in the field of engineering with evaluation of mechanical properties becomes the prime factor for recommending for specific applications. An attempt has been made here to review the available literatures in this context.

Sapuan et al. [1] evaluated tensile and flexural properties of epoxy-coconut shell filler particles at three different filler contents *viz*. 5%, 10%, and 15%, according to ASTM D 3039/D 3039 M-95a and ASTM D790-90 respectively . Experimental results showed that tensile and flexural properties of the composites increased with the increase of the filler content. Elastic moduli of the composites increased with an increase of the filler content. Singla and Chawla [2]. conducted compression and impact test by taking different weight percentage of fly ash in epoxy matrix. It was observed that the compressive strength has been increased with increase in fly ash particles. This increase is attributed to hollowness of fly-ash particles & strong interfacial energy between resin & fly-ash. With increase in fly ash slight decrease in energy (Impact strength) has been observed due to decreased availability of epoxy material to bond all the fly ash particles in the matrix. Husseinsyah and Husseinsyah,and Mostapha [3] examined the effect of filler content on properties of coconut shell filled polyester composites. Polyester composite was prepared by incorporating coconut shell at different contents into polyester matrix. A catalyst, butanox M-60 was used to initiate the polymerization reaction. The effect of coconut shell content on the mechanical, water absorption and morphological properties were studied. The results revealed that increased in coconut shell content have increased the tensile strength, Young's modulus and the water absorption but reduced the elongation at break. Tensile, compression, wear and impact testing were carried out in coconut shell and coir fibre reinforced epoxy composites by Kumar and Kumar [4]. Their work showed that Rockwell hardness number increases with increase of wt% of coconut shell particle and also that the Ultimate strength equal to 30 MPa and modulus of elasticity equal to 856 MPa are achieved for 20%wt shell particle reinforced composite. Density increases with addition of shell particle in case of coir and particle composite. Here fibre reduces density. The water absorption capacity was found to be maximum for 33 to 35 wt % of coconut shell particle. Vijayaram [5] reported that the tensile and flexural strengths of the epoxy coconut filler composites were affected by the amount of filler in the composites. The tensile, flexural and compression tests of natural composites based on coconut shell filler particles at three different filler contents were carried out. It is seen that more the filler content, the higher the strength. In tensile testing, coconut filler particulate demonstrated linear behaviour with sharp fracture and exhibit higher tensile strength for higher filler particulate specimen. In flexural testing, filler composites demonstrated slightly nonlinear behaviour prior to sharp fracture.

Subham and Tiwari [6] have evaluated the effect of fly ash concentration and its surface modification on fibre reinforced epoxy composite. Investigation was done by varying fly ash concentration and modifying fly ash particles surface by a γ-aminopropyltriethoxysilane coupling agent. The DMA test result showed improvement in damping capability and thermal stability with lower concentration of fly ash. The tensile test result showed that with increase in fly ash concentration, the ultimate tensile strength and elongation at break was reduced; however silanization of fly ash showed improvement in strength when compared to unmodified fly ash at same concentration. The impact test result showed that the toughness of FRP composite was reduced due to addition of fly ash, but silanization resulted in improved 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. Bhaskar and Singh [7] evaluated the water absorption and compressive properties of coconut shell particle reinforced epoxy composites. Coconut particle reinforced composites were fabricated by reinforcing shell particle (size between 200-800μm) by wt% of 20, 25, 30 & 35 into epoxy matrix. Composite plates were made by casting in open mould. Experimental results showed that water absorption increases with the increase of wt% of particle but composite with 30%wt of coconut shell particle showed very good ultimate strength and good modulus of elasticity in compressive zone in comparison to other wt% reinforcement of particles. Ozsoy et al [8] compared the mechanical properties of chopped bamboo and chopped coconut shell reinforced epoxy composites. Three different weight fractions (6%, 8%, 10%) were used as reinforcement for composites. Tensile tests were performed according to the ASTM D638 and three point bending tests were performed according to the ASTM D790. The results were compared. As chopped coconut shell percentage increased, the tensile strength decreased. On the other hand as chopped bamboo percentage increased the tensile strength increased. As the amount of the reinforcement increased density of the composites reduced but hardness increased. Muthukumar and Lingadurai [9] investigated the mechanical properties of coconut shell dust and groundnut shell reinforced polymer matrix composite. The polymer matrix composite was developed using coconut shell powder (CSP) and groundnut shell powder (GSP) in different volume fractions. Specimens were prepared by varying weight percentage of reinforcement material (i.e. 30, 40, 50, 60, 70 weight%) and matrix material. The tensile strength curve showed with an increase of filler volume, the tensile strength goes on decreasing. The maximum flexural strength was obtained for the composite prepared with 50% CSP&GSP filled while the flexural strength was minimum for the composite prepared with 70% CSP&GSP. The mechanical properties of particulate coconut shell and palm fruit polyster composite was investigated by

Durowaye et al. [10]. Coconut shell and palm fruit particles were separately and thoroughly blended with polyester resin. One gm of catalyst and 0.5g of accelerator were added to the mixture to achieve a good homogenous interfacial interaction. Particles of the reinforcement with different weight fractions (5, 10, 15, 20, 25 and 30) were added. The coconut shell particles reinforced polyester composite has the highest tensile strength value of 70MPa at 10wt % reinforcement and both the composites show increasing strain (ductility) as reinforcement concentration increases. Both flexural strength and modulus of the two composites increased with increase in reinforcement content at 10wt %. For coconut shell particulate polyester composite, the hardness value increases up to a maximum value of 208 BHN and the impact strength increases up to a maximum value of 4.76J at 10wt %. Beyond this reinforcement value, its impact strength decreases.

Vignesh et al. [11] analyzed the mechanical properties of alkali treated coconut shell powder - polymer matrix composites. The coconut shell powder was treated with different levels of soaking time and concentration of alkali solutions. As a result of alkali treatment, modification occurred in the surface of coconut shell powder. Coconut shell powder –Epoxy composite was fabricated by using hand layup process and the mechanical properties (Flexural, Impact strength, Hardness) were evaluated. These particles were having higher tensile strength, higher flexural strength good elasticity, and excellent resilience and in turn it would not induce a serious environmental problem like in plastic components. Venkatesh [12] fabricated and tested coconut shell powder reinforced epoxy composites having different weight fractions of coconut shell for different grain sizes using hand layup method. It was found that the density decreases as the weight percentage of fibre increases and with the increase of mesh size. As the reinforcement increases the hardness increases, the maximum value was obtained for composite prepared with the 30% shell dust of 240 mesh. Further the maximum tensile strength was obtained for the composite prepared with the 20wt % of 170 mesh coconut shell particulate. Gopal and Bhupesh Raja[13] have studied the sea water absorption behaviour of coconut shell powder/jute fibre mat/glass fibre reinforced epoxy composite laminates. It was observed that the water absorption of jute mat with 45^0 stitching without coconut shell powder was very less and that of jute mat and glass fibre with shell powder was moderate. The water absorption might have been higher due to edge effects and interplay voids in the laminates.

Manjunath and Sabeel [14] investigated the mechanical properties of coconut shell particle reinforced epoxy composites.The results showed that tensile, impact and flexural properties decrease due to increase in the particle size and volume fraction of coconut shell. However the hardness of the composites increase with same treatment. The mode of fracture was also determined with fractographic analysis with different loading conditions..

III. SCOPE

a. To prepare composites of coconut shell dust, fly ash and epoxy by hand layup technique using a suitable die developed in house
b. The weight fractions of the shell dust may be varied from 10, 15, and 20 % in the matrix of epoxy.
c. The weight fraction of fly ash will be kept constant at 5%.
d. Mechanical properties and water absorption behaviours are to be studied by preparing test specimens as per ASTM standards and results obtained will be discussed for examining the utility of these composites in engineering fields.

IV. EXPERIMENTAL INVESTIGATIONS

Materials and methods:

The following materials have been collected from different sources for fabrication of the composite with varying coconut shell content (10, 15 and 20 %) and constant fly ash percentage (5%) by weight.

Fly ash

Sample Fly ash (Fig..1) was collected from NTPC and tested in R &D Laboratory of NTPC. The various constituents present are as in Table .1.

Fig.1 Sample of fly ash

Table 1 Constituents of fly ash

Sl.No.	Testing parameter	Test values (%)
1	Loss of ignition	1.2
2	Silica	56.5
3	Ferris oxide	11.0
4	Alumina(Al_2O_3)	17.7
5	Magnesia	5.4
6	Calcium oxide	3.2

Coconut shell dust

Coconut shell (Fig.2) obtained from Local market of Talcher, Odisha. It was crushed to desired grain size in Pulveriser at IMMT, BBSR. The shell dust (Fig.3) was used in random orientation in epoxy matrix with grain sizes between 200-500 µm.

Fig..2 Coconut shells

Fig. 3 Coconut shell dust

Composite Preparation

A wooden mould of dimension (300 x 150 x30) mm^3as shown in Fig. 4 was used for casting the composite sheet.

Fig. 4 Casting of the composites

The samples have been manufactured with different weight fractions of coconut shell dust i.e. 10, 15 and 20 % respectively. The size of coconut shell dust was measured by sieve shaker and found to be 212 µm. For constant weight fraction of Fly ash, (5%) resin and hardener were thoroughly mixed with gentle stirring to minimize air entrapment .The epoxy and hardener were mixed in 10:1 ratio. The coconut shell dust was then added to the slurry for different weight ratios and mixed thoroughly. The slurry was then poured in to the mould box till the required thickness is achieved. For quick and easy removal of composite sheets, silicon spray was applied at the inner surface of the mould. Care is taken to avoid formation of air bubbles. The mould was allowed to cure at room temperature for 24 hrs. After 24 hrs the samples were taken out of the mould, cut into different sizes for further experimentation as per standard.

Test samples

The samples are cut from the laminate according to reference standard of ASTM D-638 shown in Fig. 5 and Table 3.

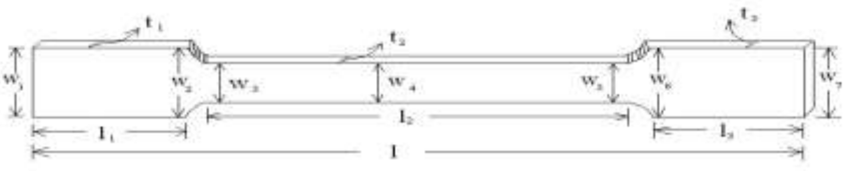
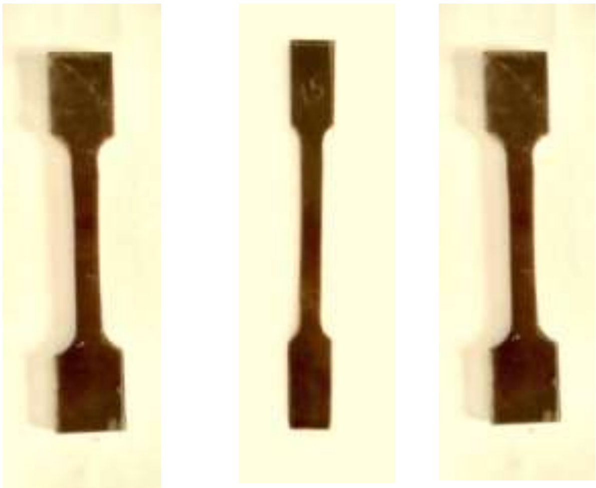


Fig. 5 ASTM standard specimen

Table 3 Dimensions of standard specimen

Specimen	l_1	l_2	l_3	l	w_1	w_2	w_3	w_4	w_5	w_6	w_7	t_1	t_2	t_3
Standard	**42**	**100**	**42**	**204**	**25**	**25**	**13**	**13**	**13**	**25**	**25**	**-**	**-**	**-**

After preparing the specimens (Fig.6 a,b,c) manually the dimensions were measured and the results are interpreted in Table. 4.



(a) **(b)** **(c)**

Fig. 6 Actual specimens prepared. (a, b, c as 10, 15, 20% of CSP)

Table.4. Actual specimen dimensions

SPECIMEN	W_1 in mm	W_4 in mm	W_6 in mm	t_1 in mm	t_2 in mm	t_3 in mm	L_1 in mm	L_2 in mm	L_3 in mm
10% CSP 1	21.36	14.96	25.43	4.1003	4.4501	4.4312	43.126	103.016	50.134
10% CSP 2	23.24	14.62	25.89	4.1304	4.3612	4.3612	40.314	103.036	49.316
10% CSP 3	23.96	14.87	26.24	4.1187	4.3955	4.3263	43.125	102.104	49.831
15% CSP 1	27.63	14.32	28.36	5.1421	5.122	5.195	40.28	103.14	44.96
15% CSP 2	26.93	15.17	29.27	5.1786	5.1286	5.248	43.21	102.68	45.89
15% CSP 3	27.28	14.96	28.74	5.1692	5.1315	5.163	41.24	105.12	45.21
20% CSP 1	27.31	14.72	27.67	5.0036	5.002	4.9836	44.21	103.218	43.234
20% CSP 2	29.43	14.98	28.12	5.0071	5.2132	5.1249	47.82	106.824	45.682
20% CSP 3	28.68	14.52	27.97	5.0086	5.1426	5.0834	44.98	105.132	47.891

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Tensile test

The tensile test has been carried out at CIPET, Bhubaneswar. using Universal Testing Machine (Fig. 7) having specification:

Make: ADMET expert 2600 series

Model no.-2653, Load capacity-50KN, Maximum speed-508 mm/min, Minimum speed-.00005 mm/min, Maximum force at full speed-50 KN, Total cross head travel 1092 mm, Space between columns-558 mm, Height-2159 mm,Weidth-1041 mm , Depth-584 mm, Weight-730 Kgf

Fig.7 UTM for tensile test

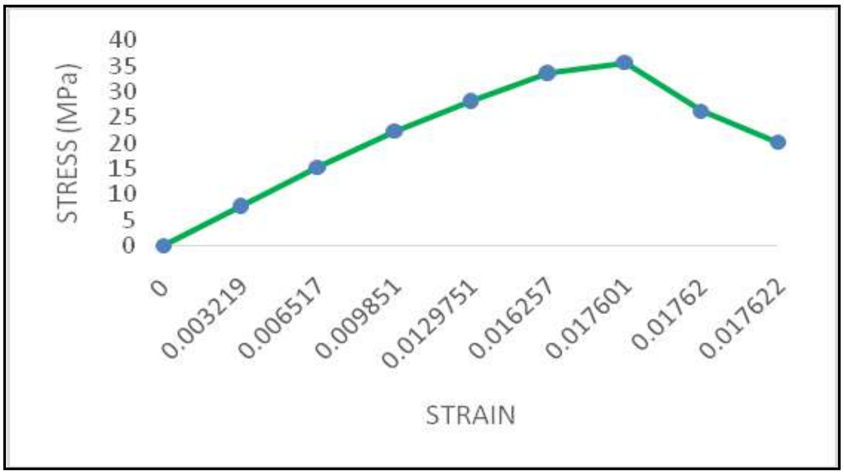

Fig.8 Stress-strain curve for composite with 10% CSP

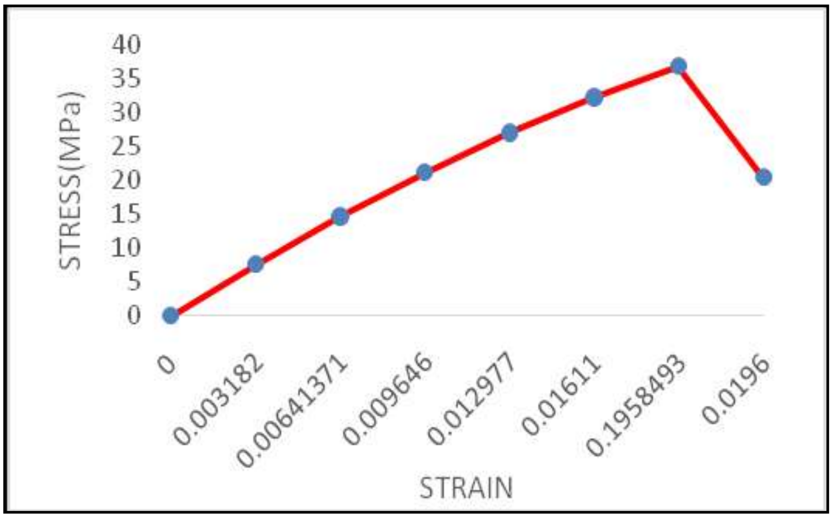

Fig. 9 Stress-strain curve for composite with 15% CSP

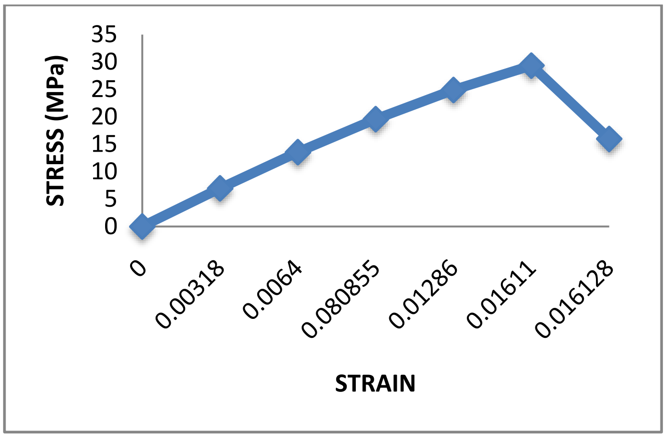

Fig.10 Stress-strain curve for composite with 20% CSP

Table 5 Tensile Strength of specimens

Samples	Tensile Strength in MPa
10% csp	35.63
15% csp	36.99
20% csp	29.35

The stress –strain curves for all the composites have been plotted in Fig.8, 9 and 10. The tensile strength of each specimen with varying percentages of shell dust has been indicated in Table 5.

Water absorption tests

The water absorption test has been carried out by soaking the (2"x2") circular samples in water and taking percentage of weight gain after 24hrs and 48hrs respectively as per standard ASTMD 570-98 in the Table.6 and 7. The samples have been shown in Fig. 11 a, b, c. (10, 15 and 20% CSP respectively)

(a) **(b)** **(c)**

Fig.11. Water Absorption Test Samples.

Table .6 Water absorption test results after 24 hrs

SPECIMEN	Dry weight in gm. (W1)	Weight after 24 hr. of water absorption (W2)	Difference in gm. (W2- W1)	% gain in weight {(W2- W1)/ (W1)} x 100
SPECIMEN A (10%CSP)	9.8101	9.8724	0.0623	0.6350
SPECIMEN B (10%CSP)	12.1696	12.2324	0.0628	0.5160
SPECIMEN C (15%CSP)	9.4052	9.4567	0.1515	1.5044
SPECIMEN D (15%CSP)	10.0741	10.1324	0.0583	0.5787
SPECIMEN E (20%CSP)	13.2826	13.4016	0.1190	0.8959
SPECIMEN F (20%CSP)	10.4433	10.6079	0.1646	1.5761

Table 7 Water absorption test results after 48 hrs

SPECIMEN	Dry weight in gm. (W1)	Weight after 48 hr. of water absorption (W2)	Difference in gm. (W2- W1)	% gain in weight {(W2- W1)/ (W1)} x 100
SPECIMEN A (10%CSP)	9.8101	9.8934	0.0833	0.8491
SPECIMEN B (10%CSP)	12.1696	12.3467	0.1771	1.4552
SPECIMEN C (15%CSP)	9.4052	9.5167	0.1115	1.1855
SPECIMEN D (15%CSP)	10.0741	10.2341	0.1600	1.5882
SPECIMEN E (20%CSP)	13.2826	13.5217	0.2391	1.8010
SPECIMEN F (20%CSP)	10.4433	10.7879	0.3446	3.2997

Micro hardness test

The micro hardness test has been carried out in the Vicker's hardness testing machine. Results show that hardness increases with increase in % of CSP as indicated in Table 8.

Table 8 Hardness Test Results.

Specimens	First reading	Second reading	Third reading	Average(VHN)
Sp-1(10%CSP)	13.727	17.990	15.944	15.880
Sp-2(15%CSP)	16.471	17.715	14.108	16.098
Sp-3(20%CSP)	16.422	17.338	16.880	16.880

Microstructure of samples

Microstructures of the specimens have been examined under optical microscope with 10x magnification. The structures have been shown in Fig.12 a, b and c. The analysis showed better uniform distribution of reinforcement in sample with 15 % CSP compared to others.

(a)

(b)

(c)

Fig.12 Microstructure analysis. a- 10%, b- 15%, c- 20 %

V. RESULTS AND DISCUSSION

Out of the results obtained as above it may be concluded that the tensile strength of the composites is increasing with increase in percentage of shell dust but further increase results in reduction of strength as in case of 20 % sample. As far as water absorption capacity is concerned all the composites have shown excellent properties as the gain in weight after 24 hrs is much less than recommended as per standard (Less than 2%). However while conducting the tests for 48 hrs it is seen that the water absorption capacity of one of the specimen with 20 % shell dust is little bit higher than recommended value. This might be due to higher content of shell dust. With increase in shell dust content the hardness is increasing for all the three test specimens meaning thereby the material is becoming more brittle.

VI. CONCLUSIONS

a. From the tensile test it is observed that as the percentage of coconut shell dust increases the tensile strength of the samples is increases up to 15% & then decreases for 20%
b. Further with increase in shell dust particles the hardness of the composites is increasing
c. From the water absorption test as the gain in weight is less than 2% hence moisture absorption is negligible.
d. It is also seen from the micro structure analysis that the shell dust is evenly distributed in the matrix. Fly ash presence is not significantly observable due to low magnification.
e. Because of this even distribution of filler in the epoxy matrix probably the hardness and strength values are quite optimum.
f. Out of all these samples, may be the sample with 15% of shell dust will be best suitable for mechanical applications.

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