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Mechanical Properties and absorption behavior of CSP Filled Roselle Fiber Reinforced Hybrid Composites

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Abstract

This article depicts the mechanical properties and hydrophilic behavior of a new class of multi-phase composites consisting of vinyl ester resin reinforced with Roselle fiber and filled with coconut shell particulates (CSP). Fiber reinforced Vinyl ester composites was prepared by incorporating coconut shell at four different filler contents viz. 0%, 5%, 10%, and 15%. The mechanical properties of these composites are evaluated. The results show that the tensile and impact strength of the composite increase with increase in coconut shell content, the flexural strength of the composite is a maximum of at 5% of the CSP filler content. The water absorption goes on increasing with increase of time duration and CSP filler content. The maximum of water absorption is obtained from the composite prepared with 15% CSP filler. The hardness and density of the composites are also greatly influenced by the content of these fillers.

Keywords **–** Coconut Shell powder (CSP), Roselle fiber, Vinyl ester resin, Mechanical characterization.

1. Introduction

Coconut Shell powder is a waste from agriculture product, often being used as a fertilizer to another plantation. There is a need for development of a new usage from agriculture waste, to benefit the agriculture industry as well as other industries from Coconut shell powder will reduce agriculture waste, and increase its value. PMC has various advantages; its properties are usually superior to its parent materials. This means that materials with considerably low mechanical properties might perform better mechanical properties if combined together with a suitable processing method [1,2].

Luo and Netravali [3] studied the tensile and flexural properties of the green composites with different pine apple fiber content and compared to the virgin resin. Roselle fiber is fairly coarse and inflexible. It has good strength, durability, ability to stretch, affinity for certain dyestuffs and resistance to deterioration in seawater. Roselle ropes and twines are widely used for marine, agricultural, shipping, and general industrial use. The filler materials include organic, inorganic, and metallic particulate materials in both micro and nano sizes. Various kinds of polymers and polymer-matrix composites reinforced with metal particles have a wide range of industrial applications [4]. Ahmed *et al.* [5] Carried out research work on filament wound cotton fiber reinforced high density polyethylene (HDPE) resin. Khalid *et al.* [6] also studied the use of cotton fiber reinforced epoxy composites along with glass fiber reinforced polymers. Fuad *et al.* [7] investigated the new type wood-based filler derived from oil palm wood flour (OPWF) for bio-based thermoplastics composites by thermogravimetric analysis and the results are very promising. Schneider and Karmaker [8] developed composites using jute and kenaf fiber and polypropylene resins and they reported that jute fiber provides better mechanical properties than kenaf fiber. Bahadur and Gong [9] have investigated the action of various copper compounds as fillers on the tribological behavior of PEEK. Wang et al. [10] have investigated friction and wear properties of nanometric ZrO_2 and silicon carbide filled PEEK composites with different filler proportions.

Coconut shell particulates are made from the most versatile part of the Coconut and referred to as CSP, the shell which is organic in nature and exist in powder form. Since it has good durability characteristics, high toughness and abrasion resistance properties, it is suitable for long standing use. The shell is similar to hard wood in chemical composition although lignin content is higher and cellulose content is lower [11-13]. Hence, in the present work CSP is used as filler material to investigate the mechanical strength and absorption behavior of the roselle composite.

2. Experimental Details

2.1 Composite preparation

Table 1: Description and detailed compositions of the composites

Description	Composition
C_1	Polyester (80wt.%) + Roselle fiber (20 wt.%)
C_2	Polyester (75 wt.%) + Roselle fiber (20 wt.%) + CSP (5 wt.%)
C_3	Polyester (70 wt.%) + Roselle fiber (20 wt.%) + CSP (10 wt.%)
C_4	Polyester (65 wt.%) + Roselle fiber (20 wt.%) + CSP (15 wt.%)

Natural fibers are reinforced in vinyl ester resin and four different weight proportions of Coconut shell powder (0 wt%, 5 wt %, 10 wt% and 15wt%) with average size of 300 micron are added as the filler material to prepare the composites C_1, C_2, C_3, and C_4 respectively. The composition and designation of the composites prepared for this study are listed in **Table1**. The fabrication of the composite slabs (using the fabricated mould **figure .1**) is done by conventional hand-lay-up technique shown in **Figure 2**. 2% cobalt nephthalate (as accelerator) is mixed thoroughly in vinyl ester resin followed by 2% methyl-etheyl-ketone-peroxide (MEKP) as hardner prior to fiber reinforcement. The vinyl ester resin and the hardener are supplied by local supplier of GVR Enterprises madurai. The natural fiber (Roselle) and vinyl ester resin possess Young's modulus of 72.5 GPa and 3.5 GPa respectively and a density of 2600 kg/m^3 and 1350 kg/m^3 respectively. Each specimen of fiber reinforced composite is 150×150 mm^2. A wooden mould of 155×155×4 mm^3 dimension is used. The castings are put under 24 hours for proper curing at room temperature. Tested specimens are shown in **Figure. 3**

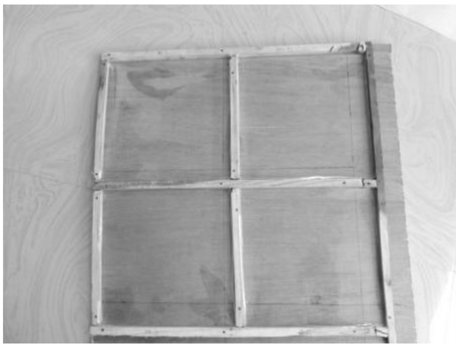

Figure 1: Fabricated wood Mold

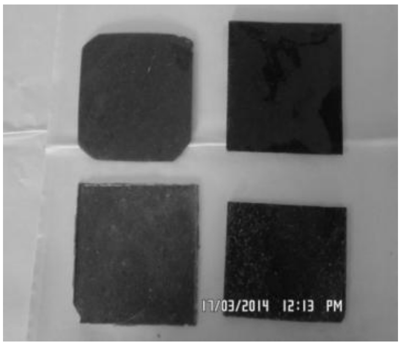

Figure 2: Specimens

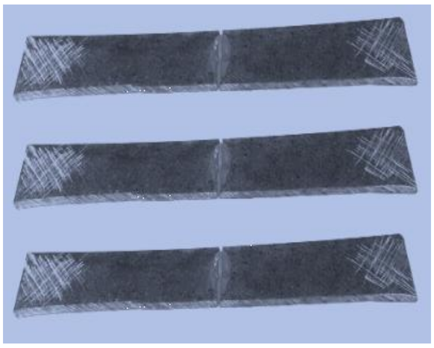

Figure 3: Tested Specimens

2.2 Mechanical Test details

2.2.1 Density

The theoretical density of a composite material can be obtained by using the following equation given by Agarwal and Broutman[10].

Each composite sample under this investigation consists of three components,namely fiber, matrix and particulate filler. The theoretical density of the composite specimen in terms of weight fraction can be obtained as per the following equation

$$\rho \boldsymbol{ct} = \frac{1}{\left(\frac{wf}{\rho f}\right)+\left(\frac{w\boldsymbol{m}}{\rho \boldsymbol{m}}\right)+\left(\frac{wp}{\rho p}\right)} \qquad (1)$$

Where, ρ and W represent the density and weight fraction respectively. The suffix m, f and ct stand for the matrix, fiber and the composite specimen respectively. The suffix 'p' indicates the particulate filler material. However the actual density (ρ_{ce}) of the composite specimen can be determined experimentally by Archimedes principle. The volume fraction of voids (V_v) in the composite samples is calculated by using the following equation:

$$Vv = \frac{\rho ct \ -\rho ce}{\rho ct} \qquad (2)$$

2.2.2 Surface hardness

The hardness property of samples produced was determined using Rockwell hardness tester on scale B with a 1.56 mm steel ball under a minor load of 3 kg and a major load of 60 kg and Brinell hardness tester with 10 mm diameter steel ball and with a test force of 500 kg applied for 30 sec.

2.2.3 Tensile strength

The tensile strength is generally performed on the flat specimens. ASTM-D3039 standard test method is employed for tensile test of composite specimens. The dimension of the samples for the test is 150 mm×10 mm×4 mm. 4 mm thickness is maintained for all the specimens. The test is performed in the universal testing machine at across head speed of 2 mm per minute. Four numbers of specimens with same composition are used to get the mean value of the tensile strength.

2.2.4 Impact and flexural strength

Notched-bar impact test provides information on failure mode under high velocity loading conditions leading sudden fracture where a sharp stress raiser (notch) is present. Brittle materials are absorbed little energy during impact failure. As plastic deformation capability of the materials are absorbed high energy. Although two standardized tests, the Charpy and Izod, were designed and used extensively to measure the impact energy, Charpy v-notched impact tests are more common practice. In this study we used the Charpy impact test for measuring the impact energy.

The 3-point bend test is conducted as per ASTM standard (D2344-84) using the same UTM. The data recorded during the 3-point bend test is used to evaluate the flexural strength (F.S.) using the following equation:

$$\text{FS} = \frac{3PL}{2bt^2} \qquad (3)$$

Here, P is the maximum load applied, b is the width of specimen and t is the thickness of the specimen and L is the span length of the sample.

2.2.5. Absorption Test

Long term water immersion method was used to determine the absorption behavior of composites. The composite sample was placed in a beaker with water at room temperature. At the end of 24 hours one of the sample is removed from the water at a time, all surface water wiped off with a dry cloth and weighed immediately and then replaced in the water and this procedure was repeated at every 24 hours till all samples were tested and the data were recorded. The percentage increase in weight was calculated by using equation 4.

$$\text{Inrease in weight \%} = \frac{\text{wet weight} - \text{condintioned weight}}{\text{conditined weight}} \text{ X } 100 \qquad (4)$$

3. Results and Discussion

3.1 Mechanical properties

In the present investigation, the theoretical and measured densities of Roselle-vinyl ester composites with CSP filler along with corresponding values of volume fraction of voids are presented in **Table 2**. It is observed that the theoretical values of density are not equal with the experimental values. The densities decrease with increase in filler content. The volume fraction of voids also increases with increase in CSP content. The percentage of void content in the composite specimen increases with increase in CSP content. A maximum reduction is found with Roselle-vinyl ester composites filled with 15 wt. % CSP with a maximum void percentage of 6.66.

Surface hardness is considered to be one of the important factors in composites for determination of wear rate. In this investigation both the Rockwell Hardness Test and Brinell Hardness test are used for measuring hardness values of different composites. The measured hardness values of all the four specimens by Rockwell Hardness Test are presented in **Figure 4**. It can be seen that the Rockwell hardness is increasing with the increase in filler content. However further increase in filler content decreases the hardness value. The experimental result shows the 10 % coconut shell reinforced polymer (C_3) gives the maximum value of 62HRC. Further increase in filler content to 15% gives a decrease in hardness value to 59HRC.

Table 2: Measured and theoretical densities

Composites	Measured density (gm/cc)	Theoretical Density (gm/cc)	Vol.Fraction of voids (%)
C_1	1.36	1.38	1.44
C_2	1.29	1.32	2.27
C_3	1.21	1.26	3.96
C_4	1.12	1.20	6.66

The measured hardness values of all the four specimens by Brinell Hardness Test are presented in **Figure 5**. It can be seen that the Brinell hardness is relatively higher in 0% CSP filler and the value decreased by 5 % of CSP and increasing with the increase in filler content up to 10%. However, further increase in filler content decreases the hardness value. In this study shows the 10% CSP filler polymer (C_3) gives the maximum value of 40HBS. Further increase in filler content to 15% gives a decrease in hardness value to 37HBS.

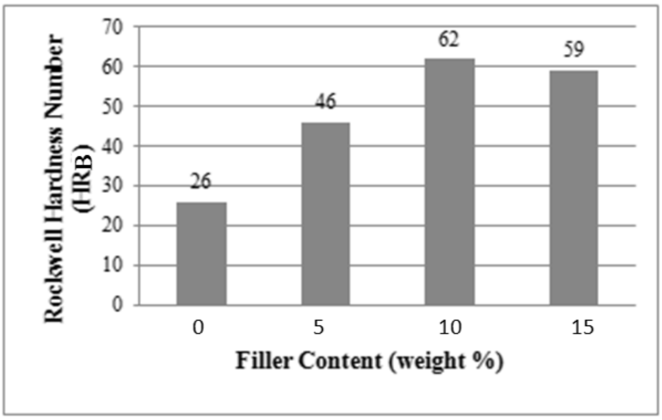

Figure. 4: Variation of Brinell hardness of the composites with CSP filler content

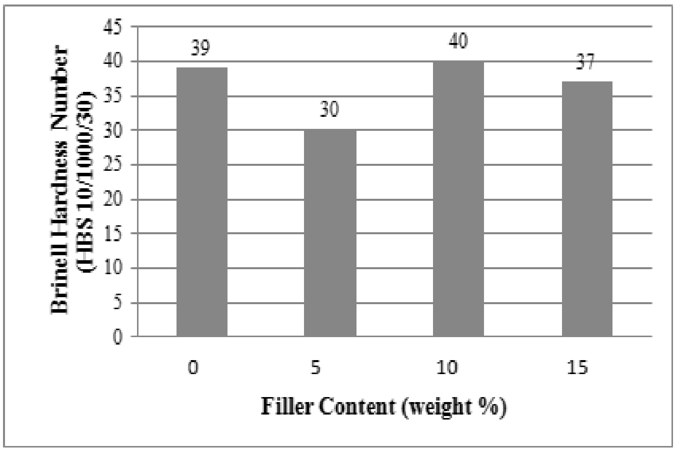

Figure. 5: Variation of Brinell hardness of the composites with CSP filler content

The mechanical strength values of different composites recorded during the tests are given in **Table 3**

Table 3: Mechanical Strength values of different composites

Composites	Rockwell hardness Number (HRB)	Brinell hardness number (HBS)	Tensile strength (MPa)	Flexural Strength (MPa)	Impact strength (J)
C_1	26	39	25.11	70.23	5.89
C_2	46	30	26.68	79.84	13.93
C_3	62	40	31.39	74.55	13.93
C_4	32.17	66.72	59	37	17.97

The tensile properties of Roselle-vinyl ester composites filled with CSP are shown in **Figure 6.** There is a gradual increase in tensile strength from a minimum of 25 MPa to a maximum of 32 MPa of Roselle-vinyl ester composites filled with 15 wt.% of CSP. The increase of tensile strength clearly indicates that inclusion of CSP and fiber optimizes the load carrying capacity of the composite specimen. This may be due to the optimum interfacial bond strength between CSP particulate and vinyl ester and may also be due to the regular CSP particles.

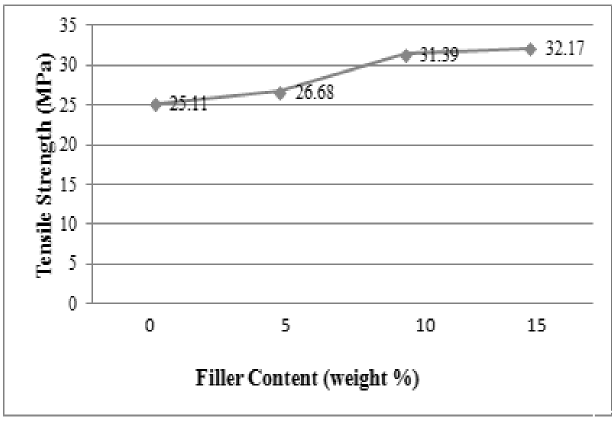

Figure. 6: Variation of tensile strength of composites with filler content

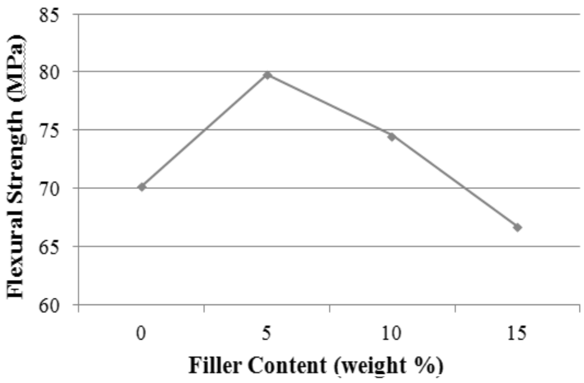

Figure. 7: Variation of flexural strength of Composites with CSP filler content

The flexural properties of Roselle-vinyl ester composites filled with CSP are studied and it is found that the flexural strength of the composite initially increased from 0% of CSP filler content and it is a gradual decrease from a maximum of 80 MPa for a minimum of 66 MPa as shown in **Figure 7**. The decreasing flexural strength shows the variation in flexural strength for different weight fraction of Roselle vinyl ester composites filled with CSP. The flexural strength curve illustrates that, the maximum flexural strength is obtained for the composite 5% CSP filled.

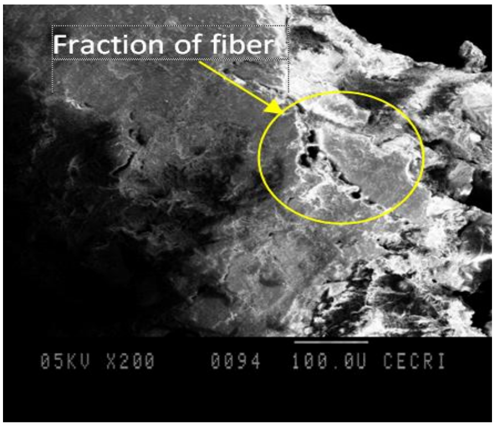

Figure. 8: SEM Image of Tensile fracture Surface

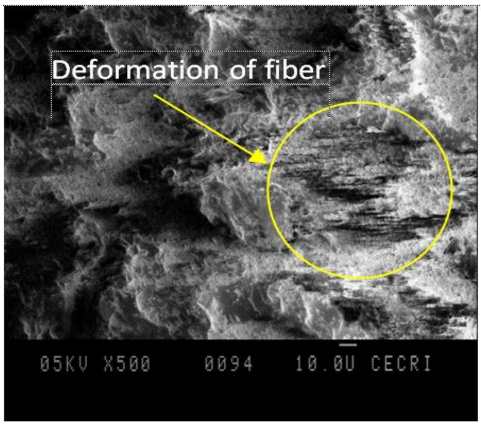

Figure. 9: SEM Image of Flexural Surface

The SEM image of fracture surface shows that the fracture of the fiber (**figure.8**). This indicates that although local plastic deformation occurs in that area (**Figure.9**).

The impact strength properties of Roselle-vinyl ester composites filled with CSP are studied and it shows that the resistance to impact loading of Roselle-vinyl ester composites filled with CSP improves with an increase in filler content as shown in **Figure 10.** From figure 10, it is observed that resistance to impact loading of reinforced composites is more than the unreinforced composites.

The water absorption results for various samples which are prepared and tabulated in **table.4**. Roselle-vinyl ester composites filled with CSP filler with different weight fraction were plotted in **figure.11**. The water absorption curve illustrates that the minimum and maximum water absorption is for the composite preparation with and without CSP. It is also observed that an increase of CSP filler volume the corresponding water absorption percentage increases.

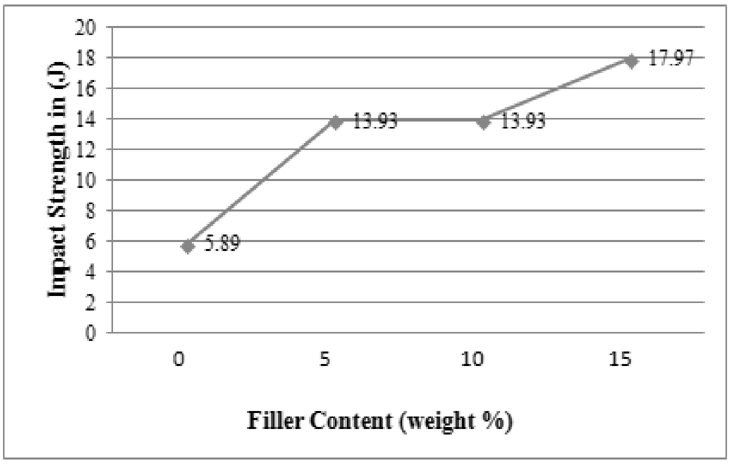

Figure. 10: Variation of Impact Strength of Composites with CSP filler content

Table 4.Water absorption behavior of different composites

Composite	0 % CSP filled	5 % CSP filled	10 % CSP filled	15 % CSP filled
24 Hrs	0.15	0.34	0.58	0.77
48Hrs	0.17	0.4	0.69	0.8
72Hrs	0.18	0.54	0.74	0.89
96Hrs	0.22	0.63	0.89	1.19
120Hrs	0.23	0.72	0.99	1.29
144Hrs	0.26	0.91	1.21	1.42
168Hrs	0.26	1.24	1.45	1.62

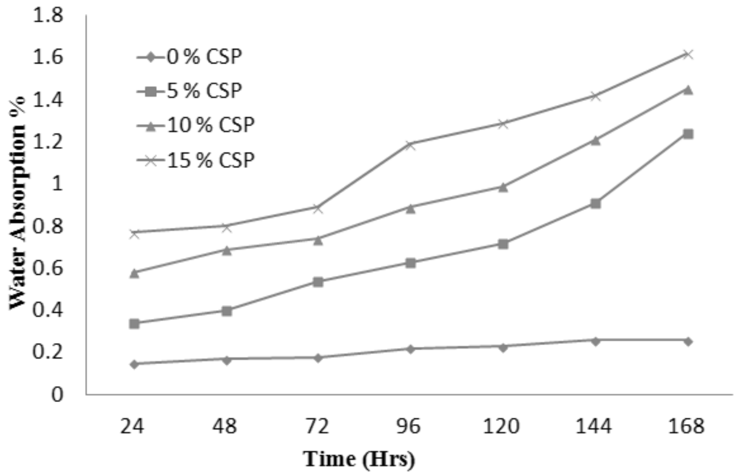

Figure. 11: Variation of water absorption of Composites with CSP filler content

Conclusions

The experimental investigation of mechanical properties like, density, tensile, impact and flexural strength of Roselle-Vinyl ester composite material is greatly influenced by the CSP filler content. The density of the composite C_4 is less than the other composites (C_1, C_2, and C3). The density value (See Table.2) shows gradual decreases with respect to increases of CSP filler. It can be seen that the Rockwell hardness increase with the increases of filler content. However, further increase in filler content decreases the hardness value. This study shows the 10 % coconut shell reinforced polymer gives the maximum value of 62HRC

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The tensile strength curve shows an increase of CSP filler content, the tensile strength goes on increasing. The maximum tensile strength is obtained from the Roselle -vinyl ester composite prepared with 15% CSP filler content.

The maximum flexural strength obtained by the composite prepared with 5% CSP filler content and minimum flexural strength obtained by the composite prepared with 15% CSP filler. The figure.7 shows that the flexural strength increases from 0% to 5%, while, the flexural strength decreases on increasing filler content from 5% to 15%.

The impact strength increases with increasing filler content from 0% to 5% and it came up to 10% further increases with 15% of the CSP filler content.

The water absorption behavior of different composite samples observes and recorded in table 4. It is also observed that an increase of CSP filler content the corresponding water absorption percentage increases.

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