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Effect of Natural Fibers on Mechanical Properties of Polymer Composites

Abstract- The mechanical behavior of coconut shell (CS) particulate epoxy composites was concentrated on keeping in mind the end goal to create designing materials for modern application. Minute of the support with various weight portions (5, 10, 15, 20 and 25) wt%. Epoxy and composite materials were prepared by hand lay-up molding. The physical properties are thermal conductivity while the mechanical properties were hardness, tensile properties, impact properties, and flexural strength. The resulting composites of thermal conductivity $0.1005 \text{ W/m}\cdot\text{c}^\circ$ that is lower than pure epoxy and commonplace materials utilized for home-structures. As for the mechanical properties, composite materials with (Epoxy+25%CS) has the maximum hardness of (76.6) shore D, The ultimate tensile strength of 33.42MPa was obtained from (Epoxy+25%CS), while the elongation at fracture with addition in filler concentration of 1.50 % was obtained from (Epoxy+25%CS) is lower than other composites. The highest impact strength, fracture toughness was 80J/m^2 , $12.87 \text{ MPa}\cdot\text{m}^{1/2}$ respectively. Flexural strength & shear stress of the composite materials with addition in reinforcement content at 5wt % & 10wt% (39, 40.5)Mpa & (1.95, 2.03)Mpa respectively while is other composites.

Keywords- Epoxy, coconut shell, thermal conductivity, mechanical properties.

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1. Introduction

Composites materials can be defined as mixed materials having new characteristics of the original components. The important properties of the composites materials are stiffness, high strength with low density and this allows reducing the weight in the final part [1]. The natural fiber reinforced composite gives low maintenance requirements, high stress to weight ratio, high corrosion, and impact resistance, nonconductive, avoid electrical hazards, reduced cost, simple establishment because of lightweight and fire retardant [2]. Durowaye et al. had studied the mechanical behavior of polyester composites with coconut shell and palm fruit particulate was concentrated on keeping in mind the end goal to build up a designing material for modern applications 1g of impetus and 0.5g of quickening agent were added to the blend to accomplish decent uniform interface collaboration. Minutes of the support with various weight divisions (5, 10, 15, 20, 25 and 30) wt % were added to 95g, 90g, 85g, 80g, 75g and 70g comparing weight of polyester resin. For the 5% weight of support, there is a comparing 95g of polyester resin. Reinforcement with 5 % of the weight we need 95 grams of polyester resin and samples have been prepared by hand lay-up. The most

astounding hardness esteem for (CS) particulate was 208 BHN while that of palm organic product particulate was 182.30 BHN [3]. Imoisili et al. had study the concentration effect of coconut shell ash (CSA) on the tensile properties of polyester composite was investigated. Five filler concentrations (5 to 25 weight %) were fabricated, Results were obtained for each of the tensile strength, elastic modulus, and micro-Hardness of the composite increases with increase in filler concentration, while percentage elongation and load at break decreases with increase in filler concentration [4].

2. Objectives of the Research

The objective of this research is to:

- 1- Prepare composites of Epoxy reinforced with natural fibers of coconut shell (CS).
- 2- Study the effect of weight fraction for coconut shell on the mechanical properties and thermal conductivity.
- 3- Study of some mechanical properties (Tensile strength, Impact strength, Hardness (Shore D), flexural shear and thermal conductivity test of the prepared composites.

3. Experimental Work

I. Materials Used

The starting materials used in the preparation of research samples consisting of coconut Shell (CS), the chemical composition of coconut shell powder consists of lignin (29.4%), pentosans (27.7%), cellulose (26.6%), moisture (8%), solvent Extractives (4.2%), Uronic Anhydrides (3.5%) and ash (0.6%) and density (1.60 gm / cm³ and density was also used [5]. In addition, the epoxy resin used has the number 105 as a specification, manufactured by Ayla Construction Chemicals under license from DCP, England, with a density 1.4 g/cm³, Table 1 Show Typical Properties of Epoxy resin [6].

II. Preparation of Composites

To prepare the samples we used the (Hand lay-Up Molding) because that samples have different shapes and sizes of composites. The weight fraction for each of reinforced material and matrix materials relations were illustrated below [7].

$$Wp = \frac{wp}{wc} \cdot 100\% \tag{1}$$

$$Wm = \frac{wm}{wc} \cdot 100\% \tag{2}$$

Where

w_p, w_c, w_m: the weight of reinforcement, composite and matrix .

W_p, W_m: Weight fraction of reinforced material and matrix materials respectively. Note that the total the weight fraction and the volume fraction are illustrated below:

$$Wp + Wm = 1 \tag{3}$$

$$Vp + Vm = 1 \tag{4}$$

4. Physical Tests

I. Thermal Conductivity

This test is performed according to ISO Standard (ISO/DIS 22007-2.2). The samples have dimensioned the diameter of 40 mm also; a thickness of 5mm Figure 1 indicates standard examples for this test.

5. Mechanical Tests

I. Hardness Test (Shore D)

This test used hardness (Shore D) and depending to (ASTM DI-2242) standard. Tests have been cut with a width of (40mm) and a thickness of (5mm). Experimental specimens are the same used in the thermal conductivity test.

II. Tensile Test

This test is to be based on (ASTM D638) [8] at room temperature. Figure 2 shows specimens for tensile test.

III. Impact Test

Impact resistance is calculated for samples from the following relationship [8].

$$Gc = \frac{Uc}{A} \tag{5}$$

Where

G_c: impact strength of material (J/m²).

Uc : impact energy (J).

A: cross- sectional area of specimen (m²).

Fracture toughness can be expressed as [9].

$$Kc = \sqrt{GcE} \tag{6}$$

Where:

K_c: fracture toughness of material (MPa.m^{1/2}).

E: elastic modulus of material (MPa).

This test is performed according to (ISO- 180) at room temperature. Samples have been cut into the dimensions (80*10*5) mm. Figure 3 shows specimens for impact test.

IV. Flexural Strength & Shear Stress

This test is performed according to (ASTM D790) at room temperature by three- point bending test machine (Lybold Harris No.36110).Samples have been cut into the dimensions(100*10*5)mm. Figure 4 shows standard specimens for this test . The flexural strength & maximum shear stress are calculated according to the equations (7, 8) [10, 11].

$$F.S = \frac{3PL}{2bd^2} \tag{7}$$

$$\tau = \frac{3P}{2bd} \tag{8}$$

Where

F.S: flexural strength (MPa).

P: force at fracture (N).

L: length of the sample between Predicate (mm).

b:thikness(mm).

d:width(mm).

τ:maximum shear stress (MPa)

P: force at fracture (N).

b:thikness (mm).

d:width (mm).

Table 1: Typical Properties of Epoxy resin [6].

| Epoxy resin | Density (g/cm ³) | Tensile modulus(GPa) | Tensile strength (MPa) | Flexural strength (MPa) |
|-------------|------------------------------|----------------------|------------------------|-------------------------|
| | 1.4 | 2.41 | 24-90 | 34-200 |



Figure 1: Thermal Conductivity experimental specimens.
 1-pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS
 4- Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS



Figure 2: Tensile test Experimental specimens.
 1-pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS
 4- Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS



Figure 3: Impact test experimental specimens
 1-pure Epoxy, 2-Epoxy+5%CS, 3-Epoxy +10%CS, 4-Epoxy +15%CS, 5-Epoxy +20%CS, 6-Epoxy+25%CS



Figure 4: Flexural Strength experimental specimens before & after test
 1-pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS
 4- Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS

6. Results and Discussion

I. Physical tests

Thermal conductivity: Table 2 and Figure 5 show the values of thermal conductivity for the prepared composite materials. it can be seen that the increasing in weight fraction for the prepared composite materials decreasing the thermal conductivity is due to coconut filled which was measured and their potential as thermal insulator

to be utilized as parts for house living was evaluated and contrasted with warm conductivities of conventional building materials of the range of study [12]. This shows a further increment in coconut shell stacking starting here on may give minimal warm conductivity diminishment.

Table 2: Thermal conductivity for (Epoxy) reinforced with groups [A₁, A₂, A₃, A₄ and A₅]

| Type of composites | Thermal conductivity (K) W/m.c° |
|--------------------------------|---------------------------------|
| Pure Epoxy | 0.2386 |
| A ₁ Epoxy +5%CS | 0.2177 |
| A ₂ Epoxy +10%CS | 0.2008 |
| A ₃ Epoxy +15%CS | 0.1522 |
| A ₄ Epoxy +20%CS | 0.1326 |
| A ₅ Epoxy +25%CS | 0.1005 |

7. Mechanical tests

I. Hardness shore (D)

The results of Shore (D) hardness for the epoxy reinforced with (A₁, A₂, A₃, A₄ and A₅) groups are illustrated in Table 3 and Figure 6. We can note that the hardness values of the composite increases with the weight fraction of coconut shell content within the matrix of the composite. The hardness will keep increasing with increasing weight fraction, and the concept of hardness can be adopted as a measure of plastic deformation, where material will suffer under the influence of external stress and the addition of particulate fillers will contribute in raising the hardness because of increased resistance to plastic deformation [13].

II. Tensile strength

Table 4, Figures 7, and 8 shows the resulted values of ultimate tensile strength (UTS) and elongation at break for epoxy reinforced with (A₁, A₂, A₃, A₄ and A₅). Figure 8 shows the effect of fillings content to test the tensile strength of the composites (epoxy /CS). The tensile strength of the composites decreased with addition of 20wt% filler content and then started to increase with increasing filler content. Tensile strength decreases in the composites 20wt% filler content as possible and that the reason for the deficient of coconut shells in matrix. The coconut shells have high lignin content, which is 29.4%. The bio-flour materials are mainly composed of a complex network of three polymers: cellulose, hemicelluloses and lignin. Lignin not only holds the bio-flour together but also it works to strengthen the cellulose molecules within bio-

flour cell wall. Thusly, the presence of lignin and cellulose in coconut shells lead to increased tensile strength of coconut shell filled epoxy composites. Figure 9 illustrates the effect of filler content on the elongation at break of (Epoxy/CS) composites. The decrease in the elongation at break upon addition of rigid fillers arises due to the decreased deformability of rigid interface between filler and epoxy matrix. When increasing fillings content, will be more weak interfacial regions between the filler and the matrix are form [14].

Table 3: Hardness shore (D) for epoxy reinforced with groups [A₁, A₂, A₃, A₄ and A₅]

| Hardness Shore (D) | Type of composite |
|-----------------------------|-------------------|
| Pure Epoxy A ₁ | 44.8 |
| Epoxy +5%CS A ₂ | 61.8 |
| Epoxy +10%CS A ₃ | 63.8 |
| Epoxy +15%CS A ₄ | 66.4 |
| Epoxy +20%CS A ₅ | 71 |
| Epoxy +25%CS | 76.6 |

Table 4: Tensile strength for epoxy reinforced with groups [A₁, A₂, A₃, A₄ and A₅]

| Type of composite | σ UTS (MPa) | Elongation at break (%) |
|-----------------------------|--------------------|-------------------------|
| Pure Epoxy A ₁ | 14.50 | 8.10 |
| Epoxy +5%CS A ₂ | 18 | 6.30 |
| Epoxy +10%CS A ₃ | 22.50 | 6 |
| Epoxy +15%CS A ₄ | 32 | 4.52 |
| Epoxy +20%CS A ₅ | 10.75 | 2.30 |
| Epoxy +25%CS | 33.42 | 1.50 |

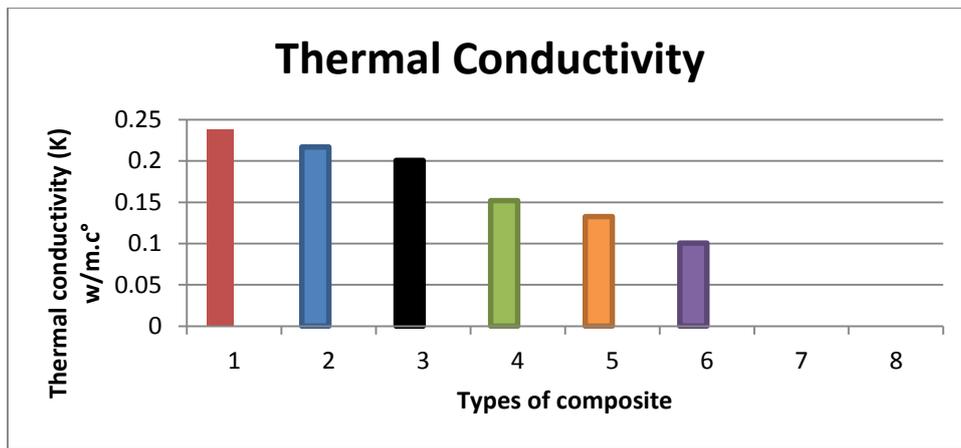


Figure 5: Thermal conductivity
 Pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS-1
 4- Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS

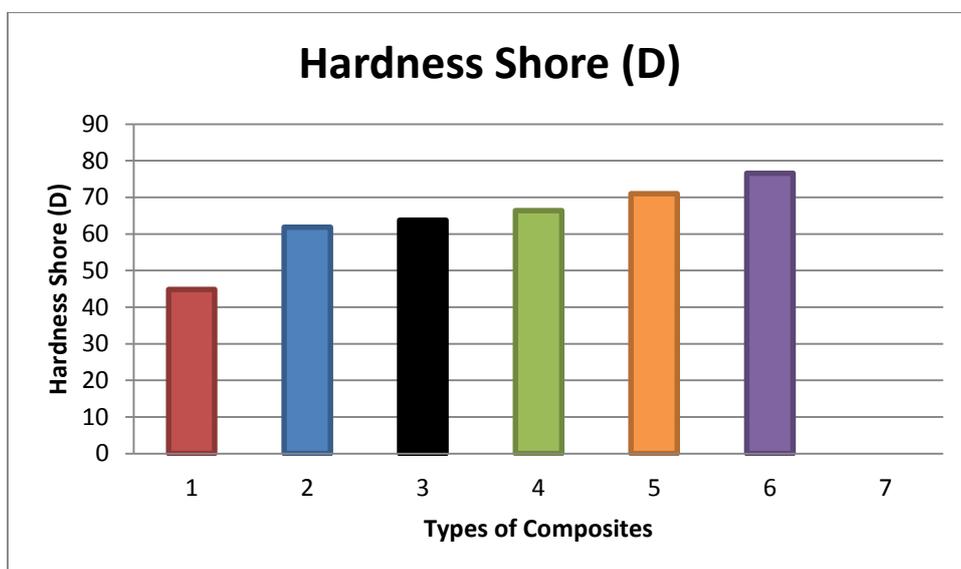


Figure 6: Hardness Shore (D)
 Pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS-1
 4-Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS

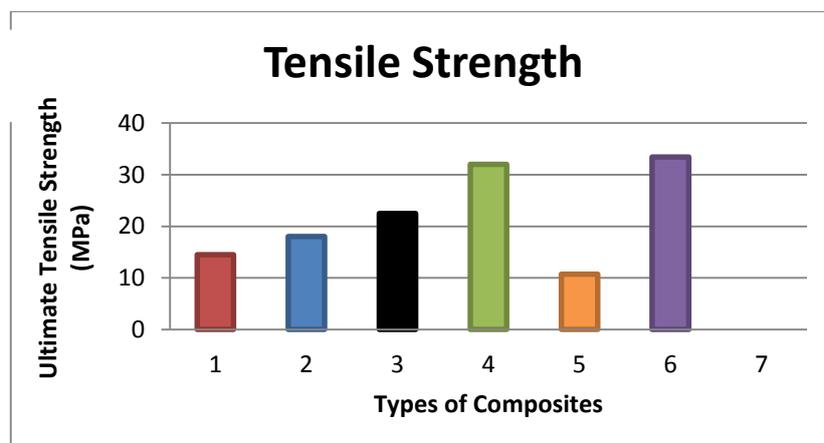


Figure 7: UTS for: 1-pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS, 4-Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS

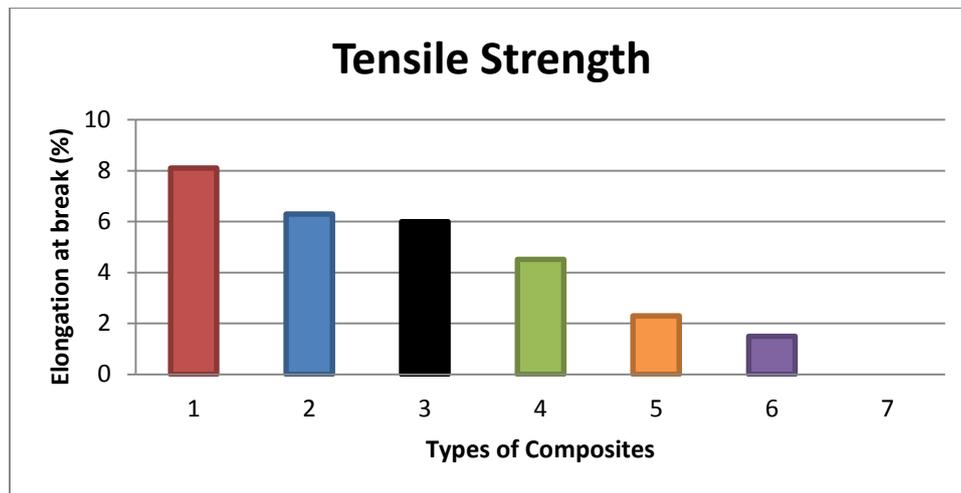


Figure 8: Elongation at break (%) for: 1-pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS 4-Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS

III. Impact energy

Table 5 shows the values of impact strength (G_c) & fracture toughness (K_c) for the epoxy reinforced with (A_1, A_2, A_3, A_4 and A_5). Figures 9 show the differences in results for each type of composite materials. The coconut shell particulate epoxy composite, highest value for the impact strength is 80 J at 25wt %, while the impact strength was less than with the reinforcement value. Impact strength of composites increased because of the increased elasticity of the composite, it will increase the distortion in the matrix. In figure10 shows that it can be seen that the fracture toughness of the composites increases with increase in the coconut shell content within the matrix of the composite.

Table 5: Impact strength of material and fracture toughness for epoxy reinforced with groups [A_1, A_2, A_3, A_4 and A_5].

| Type of composite | impact strength of material (G_c) J/m^2 | Fracture Toughness (K_c) $Pa.m^{1/2}$ |
|-------------------|---|---|
| Pure Epoxy | 55 | 1.009 |
| A_1 | | |
| Epoxy +5%CS | 27.5 | 2.56 |
| A_2 | | |
| Epoxy +10%CS | 60 | 3.80 |
| A_3 | | |
| Epoxy +15%CS | 45 | 5.11 |
| A_4 | | |
| Epoxy +20%CS | 65 | 12.46 |
| A_5 | | |
| Epoxy +25%CS | 80 | 12.87 |

IV. Flexural Strength & Shear Stress

Table 6 and Figures 11, 12, show the values of flexural strength and shear stress for the epoxy reinforced with (A_1, A_2, A_3, A_4 and A_5). In figures 11 to 12, Notice that each of the flexural strength and shear stress of the composite materials had the highest values at 5wt % and 10wt%. This is because of the strong of interfacial adhesion/bonding between the coconut shells and the matrix.

Table 6: Flexural strength & shear stress for epoxy reinforced with groups [A_1, A_2, A_3, A_4 and A_5].

| Type of composite | Flexural strength (MPa) | Shear Stress (MPa) |
|-------------------|-------------------------|--------------------|
| Pure Epoxy | 37.5 | 1.87 |
| A_1 | | |
| Epoxy +5%CS | 39 | 1.95 |
| A_2 | | |
| Epoxy +10%CS | 40.5 | 2.03 |
| A_3 | | |
| Epoxy +15%CS | 35.4 | 1.77 |
| A_4 | | |
| Epoxy +20%CS | 18 | 1.33 |
| A_5 | | |
| Epoxy +25%CS | 6 | 0.9 |

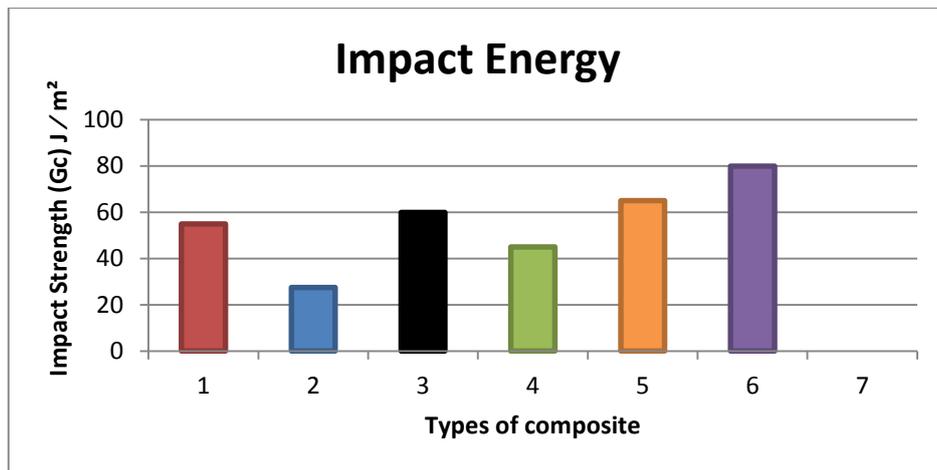


Figure 9: Impact strength (Gc) for pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS-1 4-Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS

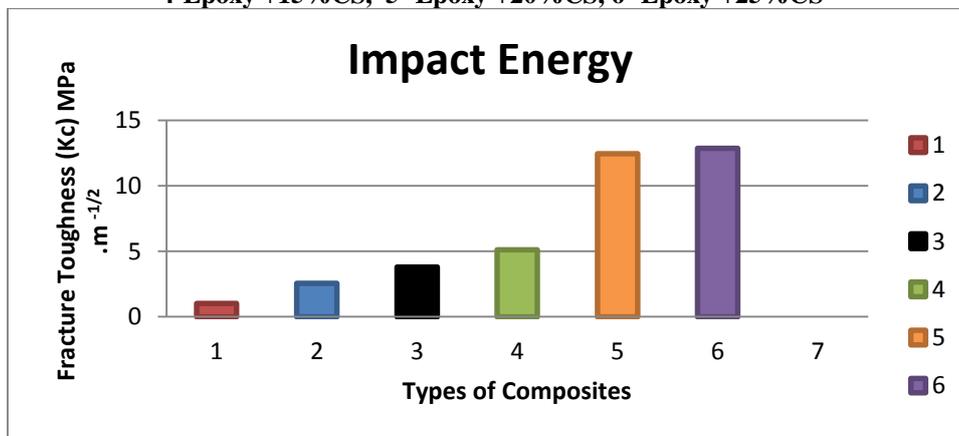


Figure 10: Fracture toughness (Kc) for pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS-1 4-Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS

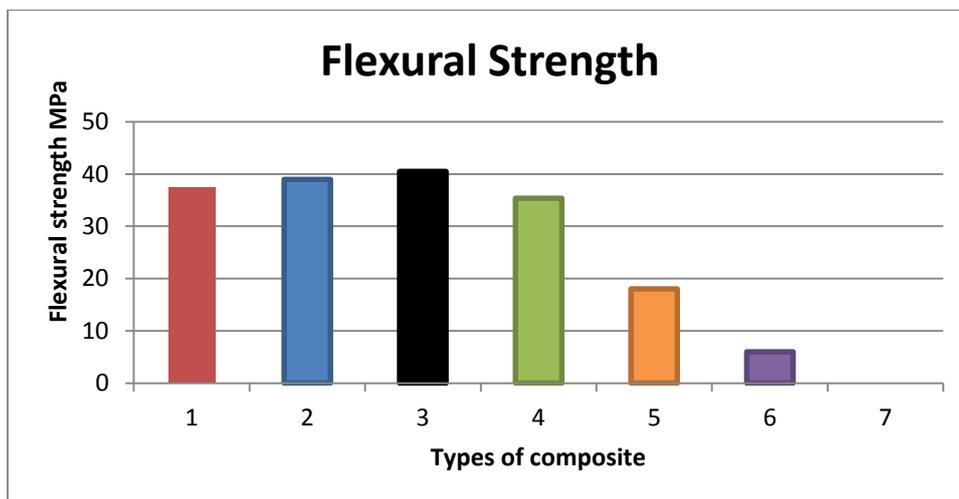


Figure 11: Flexural strength for: 1-pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS 4-Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS

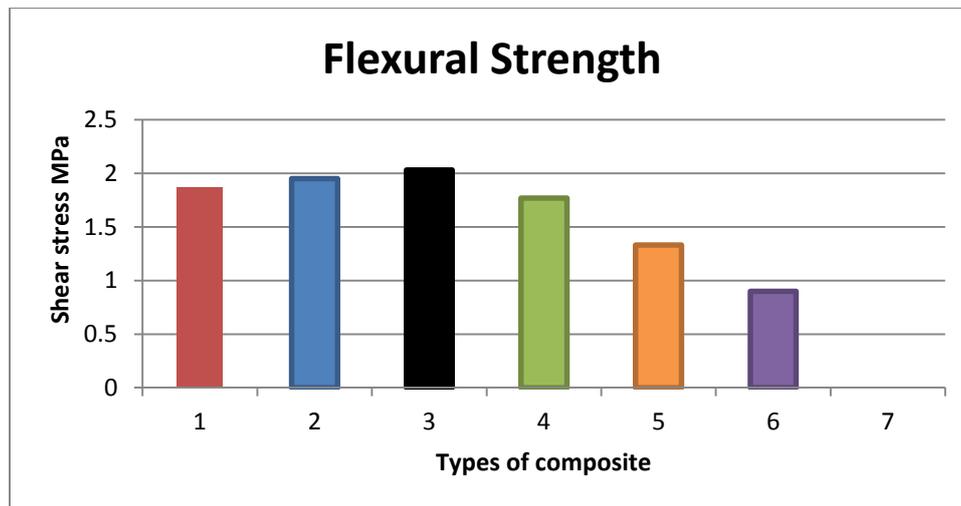


Figure 12: Shear stress for:
1-pure Epoxy, 2-Epoxy +5%CS, 3- Epoxy +10%CS
4-Epoxy +15%CS, 5- Epoxy +20%CS, 6- Epoxy +25%CS

9. Conclusions

The conclusions works are:

1- Coconut shells can be used as insulation in construction compared to traditional construction methods.

2- Composite materials have higher hardness than epoxy, composite materials with (Epoxy+25%CS) has the maximum hardness of (76.6) shore D than with other composites.

3- The tensile strength and elongation at break of the composites Have less value at 20wt% and then begins to increase with the increase in the weight fraction of coconut shell.

4- Composite materials have higher impact strength with (Epoxy +25%CS) 80 J than with other composites. The fracture toughness of the composites increases with increase in the coconut shell content within the matrix of the composite.

5- Each of flexural strength & shear stress of the composite materials increase at 5wt % &10wt% (39, 40.5) Mpa & (1.95, 2.03) Mpa respectively in reinforcement content.

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