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Flexural and Impact Properties of Epoxy Composites Reinforced with Peanut Shell Particles

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K E Y W O R D S

Epoxy, Peanut shell, Flexural strength, Flexural modulus, Impact strength, Fracture toughness

A B S T R A C T

Natural materials have been extensively used as reinforcements in polymer matrices instead of non-degradable synthetic reinforcement such as carbon, glass or aramid. The use is because of their low density, good mechanical properties, availability, and biodegradability. Peanut shell is one such natural waste filler used, and it contains cellulose, hemicellulose, and lignin. Natural fiber/particle sources are not only strong and lightweight but are relatively very cheap. This paper offers the comparison of the flexural, and impact energy test properties of the peanut shell reinforced with the epoxy resin matrix. Peanut shells add into the epoxy resin matrix with various weight fractions (2%, 4%, 6%, and 8%) and have been fabricated by hand lay-up procedure. Flexural strength and flexural modulus changed from (140MPa) to (160 MPa), and from (2 GPa) to (7.79 GPa) respectively, impact strength, and fracture toughness changed from (2.5 KJ/m^2) to (7 KJ/m^2), and from (2.23 MPa.m$^{1/2}$) to (7.07 MPa.m$^{1/2}$), respectively as a function of the particle weight fraction. The highest flexural strength and modulus obtained samples (reinforced 4% wt. peanut shell), while samples (reinforced +8% wt. peanut shell) provided the highest impact strength and fracture toughness.

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1. Introduction

Raising the requirement for cost-effective materials with approximately high strength to weight ratio has motivated researchers to use natural materials as reinforcement into composites. Today, natural materials are a favorite selection for the utilization at the structural application, these natural materials are plant-based and are lignocelluloses in nature and composed of (lignin, cellulose, hemicelluloses, and ash). These natural materials reinforced with polymer composites are comparably stiff, lightweight, and free from health hazards [1]. However, there are several drawbacks of using natural materials in the composites such as incompatible with the polymer and poor moisture resistance [2]. Polymer composite materials have achieved great importance as materials for high-performance architectural support, automotive, aerospace, public engineering and maritime applications for the past few decades. G.U. Raju and S. Kumarappa [3] investigated the tensile strength, impact strength, and water absorption of epoxy resin filled different groundnut shell particle sizes (0.5, 1, 2, and 3mm) with volume fraction (30 to 40%). The results of this investigation revealed that the samples (filled with + 30% groundnut shell), and 0.5 particle size provided the maximum tensile, impact strengths, with minimum water absorption. Aseel B. et al. [4] studied the flexural strength, hardness shore D, density, and water absorption of polymeric composite constituents from epoxy resin filled with (6% v.f) glass fiber and (3% and 6% v.f) rice husk ash, carrot and sawdust. Results indicated that flexural strength, hardness shore D, density and water absorption, increased with the addition of 6% rice husk ash, carrot, and sawdust. Akindapo J. Olaitan et al. [5] studied the tensile strength, flexural strength, impact strength, and hardness for sample epoxy resin filled with 2.5%, 5%. 7.5%, 10%, 12.5% & 15% weight fraction rice husks and groundnut shell. Results showed that samples reinforced with groundnut shell have superior tensile strength, flexural strength, impact strength, and hardness than samples reinforced with rice husk. R. Haitham and R. Alaa [6] investigated the influence of different weight fractions (4%, 8%, 12%, and 16%) of eggshell particles reinforced with epoxy resin on hardness shore D, tensile strength, impact strength, flexural, and water absorption. Results indicated that samples with 16% w.f eggshell particles filled into epoxy resin have the highest value of hardness shore D, tensile strength, impact, and flexural strength, while the same 16% weight fraction showed less value of water absorption.

The scope of this study is to discuss the perspectives of utilizing lignocellulosic (peanut shell) plant residue as reinforcing filler for thermoset polymer. These waste materials are a low-cost by-product, environmentally friendly and practical sustainable raw materials, also investigate the effect of these wastes on flexural strength, flexural modulus, impact strength, and fracture toughness, and to identify the best weight fraction of (peanut shell) which gives good mechanical properties for structural applications.

2. Materials and Method

I. Materials

The following primary raw materials were utilized in this study work; Epoxy resin and peanut shell. Epoxy resin (EUXIT 50 KI) produced by (Al-Rakaez Building Materials in Amman) made in (Egypt). Table 1 lists the mechanical and physical properties of epoxy used in the study by the company specifications [7]. The peanut shell gathered from local sources like farmers in rural areas and available at very low cost, therefore it is an ideal filler material in this regard. The peanut shells were washed with distilled water frequently to remove dust, soluble impurities, and dried in the sun for several days. Figure 1 displays the steps of preparing a peanut shell particle. The dried peanut shell converted into particles using a hammer mill for 1 hour to obtain a particle with the medium size of (121.6 μm) by using analysis technology (MASTERSIZER 2000) as presented in Figure 2

Figure 3 shows the chemical composition of peanut shell and SEM images of peanut shell at 50x and 100x, respectively.

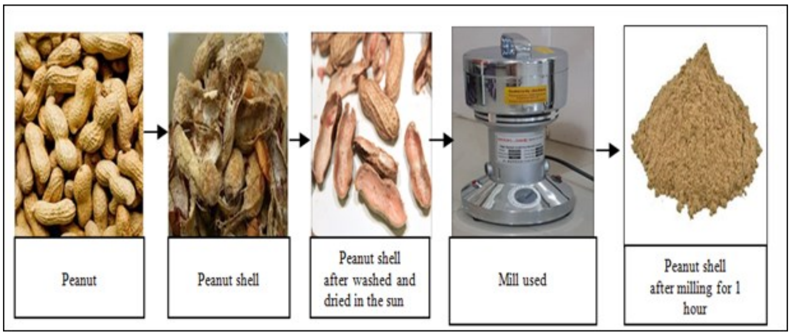


Figure 1: Steps in preparing peanut shell particles

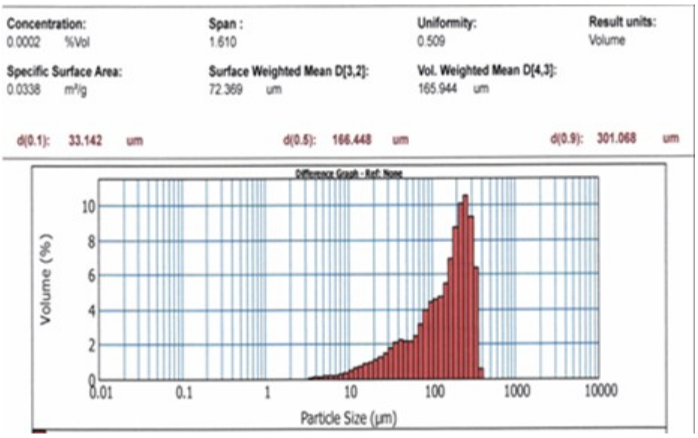
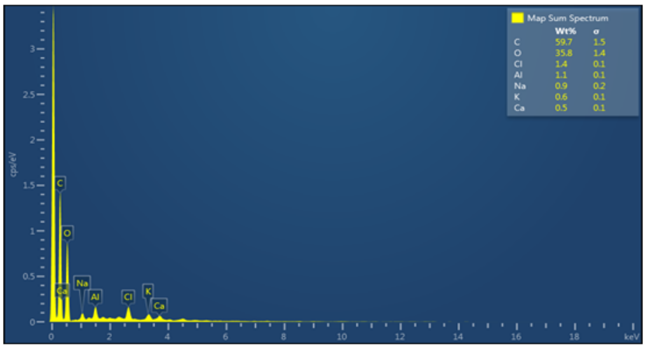
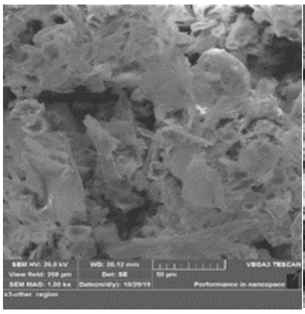
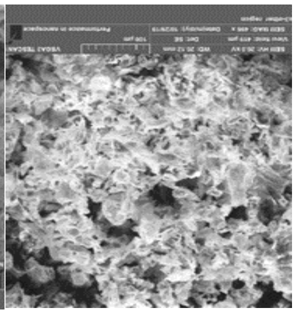


Figure 2: Volume of Peanut shell particle size after milling



(a)





(b) **(c)**

Figure 3: (a) The chemical composition of the peanut shell, (b and c) SEM images of peanut shell at 50x and 100x respectively

Table 1: Mechanical and physical properties of epoxy resin [7]

Viscosity (Poise)	Young's modulus (GPa)	Linear shrinkage (%)	Bending property (N/mm2)	Volume shrinkage (%)	Application temperature (C^0)	Density (gm/cm^3)
1.0	23	2.7-10	45	3.5	5	1.05

Table 2: The mechanical properties of peanut shell [8]

Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break %	Density (Kg/L)
55-70	1-5	2.7-10	0.902

II. Preparation of composites

A mold with a dimension of 200 mm × 200mm × 5mm was utilized to provide the polymer composite samples by hand lay-up method. A layer of wax was applied to the mold in order to easily take out the sample of the mold. Peanut shell reinforced with epoxy resin samples were prepared using different weight fractions (2%, 4%, 6%, and 8%). Peanut shell powder and epoxy resin were mixed thoroughly to get a homogeneous mix. After adding the suitable amount of epoxy resin and hardener the mix was again stirred for 10 minutes and placed in the mold and compressed uniformly. Putting the samples after out of the mold in the furnace at 50ºC to 60ºC temperature for 60 minutes in order to enhance bonding between polymer and filler materials [9]. Details composition of sample composites is presented in Table 3

Table 3: Designation of composition

Samples	Composition
C0	100% Epoxy resin
C2	98% Epoxy + 2% peanut shell
C3	96% Epoxy + 4% peanut shell
C4	94% Epoxy + 6% peanut shell
C5	92% Epoxy + 8% peanut shell

III. Flexural test

Figure 4 shows the standard dimensions of the flexural sample according to ASTM D 790- 86 [10]. Flexural strength and flexural modulus can be determined by the following equation [1, 2].

Flexural Strength $F.S = \frac{3PL}{2bd^2}$ (1)

Where:

F.S: Flexural strength (MPa).

L: support span (mm).

b: Width of the specimen (mm).

d: Depth of the specimen (mm)

The flexural modulus (E_F) can be determined by using the equation below:

Flexural modulus $E_F = \frac{L^3 P}{4bd^3 \delta}$ (2)

Where:

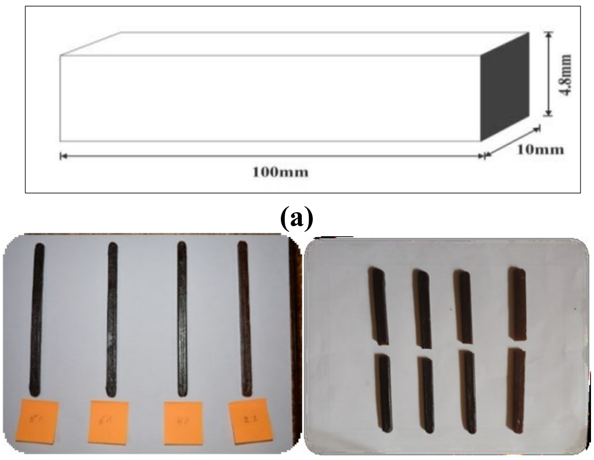
E_F= The Flexural modulus of material (MPa).

L=Length of the specimen (support span) (mm).

b= Width of the specimen (mm).

d= Depth of the specimen (mm).

δ= Specimen deflection (mm).



(a)

(b) (c)

Figure 4: (a) Specimen dimension of the flexural test (b) Sample of Peanut specimens before test (c) Sample of Peanut specimens after the test

IV. Impact test

Figure 5 shows the standard dimensions of the impact sample according to (ISO-180) [11]. Impact strength and fracture toughness can be determined by the following equation [3, 4].

$$G_C = Uc/A \qquad (3)$$

Where:

Gc: Impact strength of material (KJ/m^2).

Uc: Impact energy (J).

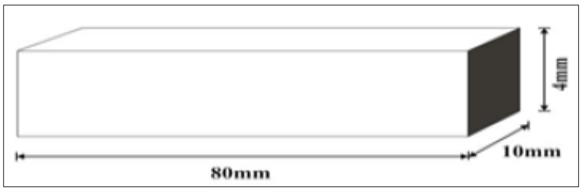
A: The cross-sectional area of the sample (m^2).

$$Kc = \sqrt{(Gc*Ef)} \qquad (4)$$

Where:

Kc: The Fracture toughness of material ($MPa.m^{1/2}$).

Ef: flexural modulus of material (Mpa)



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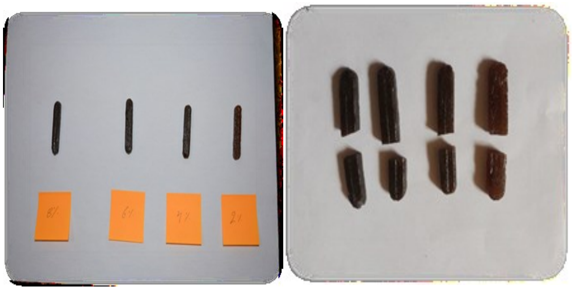

(b) **(c)**

Figure 5: (a) Specimen dimension of the impact test (b) Sample of Peanut specimens before test, (c) Sample of Peanut specimens after the test.

3. Results and Discussion

I. Flexural properties

Figure 6 exhibits the variety in flexural strength for the various weight fractions of peanut shell composites. A significant increase in the flexural strength of the composite filled with 2%, 4% weight fractions of peanut shell were noted when compared with pure epoxy, but noted that, at 6%, 8% weight fraction of the peanut shell powder the flexural strength reduced, these results agree with the literature [13]. The reason for the improvement of flexural strength of 2% and 4% weight fraction of the peanut shell powder is due to forming a good interface that provides enough stress transferal from the matrix to the filler. The addition of peanut shell at weight fraction (2% and 4%) improved adhesive properties of the composite by advancing mechanical interlocking between filler and epoxy and so enhances the stress transfer during an applied load [14], while the reason for the low flexural strength at the 6%, 8% peanut shell weight fraction due to the agglomeration and the voids of filler in the matrix resin was observed to be the main problem of the decrease in flexural strength, these results agree with the literature [15]. Therefore, the flexural strength curve demonstrated that the maximum flexural strength is reached for the composite with 4% peanut shells.

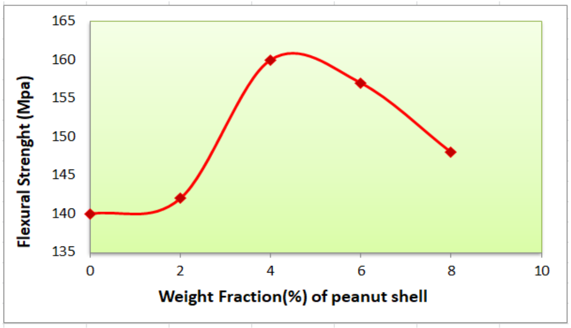

Figure 6: Flexural strength versus weight fraction of the peanut shell.

Figure 7 shows that the flexural modulus of epoxy/ peanut shell composites increased with increasing the peanut shell particle up to the weight fraction equal to 4% and then declined when added 6% to 8% weight fraction of the peanut shell particle. The peanut shell might prevent the free-flowing of the polymeric chain and so limit the capability of the polymer to deform, also these leads to forming a powerful cohesion at interfaces between epoxy resin with peanut shell thus increasing flexural modulus, these results agree with the literature [16, 17]. The main reason for the decline in the flexural modulus when adding 6% and 8% weight fractions of peanut shells, these percent of filler to reduce deformation and strain thus lead to less interface bonding and filler distribution within an epoxy [18].

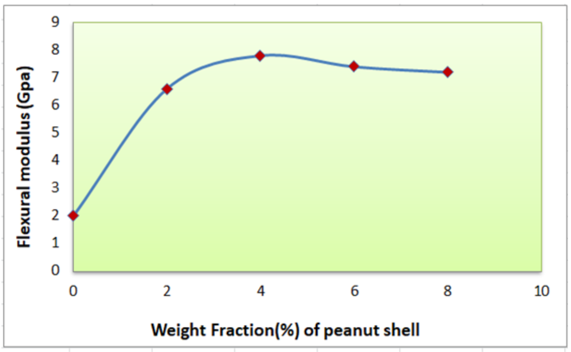

Figure 7: Flexural modulus versus weight fraction of the peanut shell.

Figure 8 shows the relationship between flexural strain and the weight fraction of the peanut shell filled with the epoxy resin. Results showed that the flexural strain, reduced as the peanut shell particle increased. Clearly, bulk epoxy has the highest flexural strain value equal to (0.030 %) whilst the less value was found in epoxy samples reinforced with 8% weight fraction of the peanut shell particle, these results agree with the literature [19].

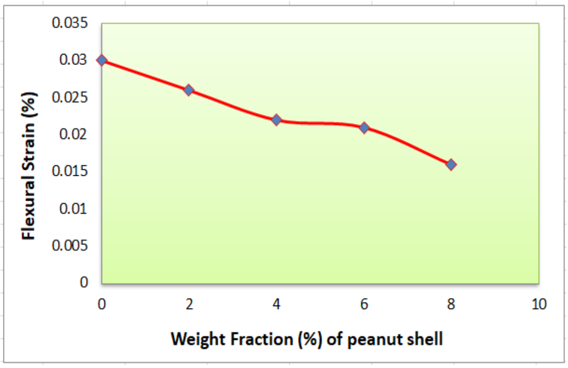

Figure 8: Flexural strain versus weight fraction of the peanut shell.

III. Impact strength and fracture toughness

The impact strength results of the peanut shell/ epoxy composite samples are shown in Figure 9. A steady increase in the impact strength with increasing the peanut shell content. This behavior indicates that (peanut shell) adhesion with the epoxy matrix is sufficient to increase the absorbed energy and it was due to the fewer void spaces in polymeric composites [20,21]. Figure 10 shows the effect of peanut shell content on the fracture toughness of the polymeric composites. The fracture toughness increased with added (2%, 4%, 8 wt%) peanut shell filler contents, due to the sufficient bonding strength between the filler and matrix. The fracture toughness decreased slightly with an added (6 wt%) peanut shell filler content due to the amount of matrix (epoxy) that is possibly not enough to carry the stress effectively through an abrupt impact in combination with the lower absorption characteristic of the filler [22]. Impact strength of filling polymeric composites rely on the nature of the reinforcement, polymer type, and filler matrix interfacial bonding strength [2].

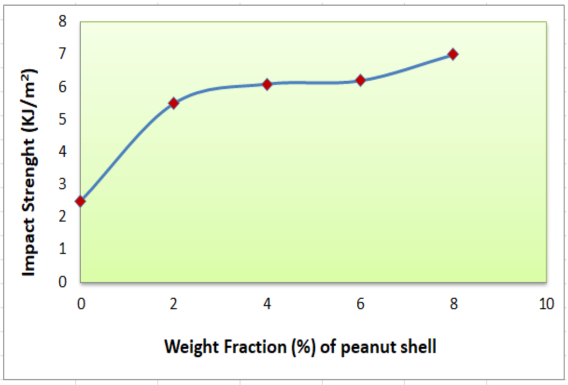

Figure 9: Impact strength versus weight fraction of the peanut shell

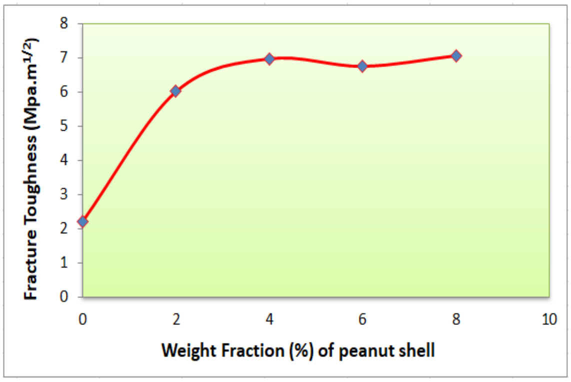

Figure 10: Fracture toughness versus weight fraction of the peanut shell

4. Conclusion

The findings of this study can be summarized as follows:

1. Successful fabrication of a peanut shell particle reinforced with epoxy by a simple hand lay-up method.
2. The flexural strength gradually decreases with added peanut shell (6 and 8 wt%) content.
3. Maximum flexural modulus value is observed for the composite prepared from epoxy filled 2% and 4wt% peanut shell particle.
4. The flexural strain decreases with added peanut shell (2 to 8 wt%) content.
5. Impact strength gradually increased with added peanut shell (2 to 8 wt%) content and the improving percentage is (180%) when compared pure specimen to specimen reinforced with the peanut shell powder.
6. Fracture toughness gradually increased with added peanut shell (2, 4, 8 wt%) content and the percentage of increase is (217%) when compared pure specimen to specimen reinforced with the peanut shell powder.

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