

# Mechanical and Electrical Characterization of Glass Fiber-Epoxy Composites with Date Pit Powder

Maher Nadher Abdullah

*Department of Mathematics, University of Diyala, 32000 Baqubah, Iraq  
maherm@uodiyala.edu.iq*

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**Abstract:** This research investigated the influence of filling date pits powder (DP) on the physical and mechanical characteristics of glass fiber-reinforced epoxy composites (EG) to form glass fiber reinforced epoxy resin filled with date pit powder (EGDP). Composite materials were produced with different DP ratios: 5%, 10%, 15%, 20%, and 25% wt. Measured results indicated a progressive enhancement in mechanical properties, comprising tensile, bending, impact resistance, shore D hardness and physical properties, consisting of dielectric constant, dielectric loss and A.C. electrical conductivity, together with water absorption relatively, when  $DP \leq 15\%$ . This enhancement was ascribed to the homogeneous filler distribution and improved interface bonding between the filler, fibers and polymer matrix. On the other hand, when the filler ratio  $DP \geq 20\%$ , a reduction in performance was detected as a result of the creation of voids and agglomerates, leading to a decrease in the mechanical and physical characteristics. As a result, 15% was regarded as the best concentration ratio that led to attaining the best compromise between mechanical and physical enhancement and structural stability of the composite.

## 1 INTRODUCTION

Recent decades have observed tremendous evolution in technology and industry, and a worldwide growth in the advancement of renewable and environmentally friendly materials, especially in the polymer composite manufacturing, which depends on conventional materials in composite matrix, fillers, and reinforcement [1]. In spite of their durability and exceptional properties, they are frequently based on inorganic or synthetic materials that are costly and hazardous to humans and the environment in the context throughout manufacturing and utilization [2]. On the other hand, the current trend has initiated to the investigation of bio-based by utilizing accessible and low-cost agricultural by-products and embedding them into fabrication applications [3].

In the Middle East, date palm is a promising bio-based agricultural resource, with all components of the tree being utilized for renewable materials and its plentiful waste [4]. An appropriate option is (DP), which constitutes of 10-15% of the weight of a date. This presents a challenge from their neglect due to their possession of lignocellulosic properties (cellulose, hemicellulose, and lignin) [5]. They can be utilized in polymer-based composite fillers by milling

them into micro-particles, which improves interfacial relative to their volume and enhancing chemical and mechanical interactions with polymer matrix [6].

In this research work, epoxy resin (ER) will be utilized as the matrix material, as it represents one of the most broadly applied matrix materials due to its advantageous mechanical properties, chemical resistance, and dimensional stability [7]. Nevertheless, its structurally weak necessitates reinforcement using high-strength materials. Glass fibers (GF) are the predominantly utilized in this domain, being characterized by strength, stiffness, low cost, etc. [8]. The benefit of merging glass fibers (GF) as the principal reinforcement and date pits powder (DP) micro- or nanoparticles as filler within the epoxy matrix is manifest to prepare a reinforced composite that improves the mechanical and physical properties [9].

Within the scientific context, this study aims to evaluate the viability of employing date pit waste as a filler in glass fiber-reinforced epoxy composites (EGDP). The physical properties were investigated. Date pits were milled into a micronized powder and incorporated with a glass fiber-reinforced epoxy matrix (EG). Mechanical tests: such as tensile strength and bending strength, impact resistance and

Shore D hardness. Electrical tests: such as dielectric constant ( $\epsilon$ ), loss tangent ( $\tan \delta$ ) and alternating current (A.C.). Humidity and environmental tests: such as water absorption. These properties were undertaken to investigate the impact of organic fillers on the performance characteristics of composites.

It is envisaged that the research outcomes will contribute practical implications for developing more eco-friendly reinforced composite systems in Iraq and other producing countries, converting agricultural by-products into industrial resources to tackle environmental challenges.

## 2 RESEARCH METHODOLOGY

### 2.1 Material and Methods

The matrix composite materials applied in this study are: LP32/Hi-Mod epoxy resin (ER) Part A and include with LP32 / Hi-Mod Part B–Hardener, mixing ratio: 1:1 by volume or weight. Widely utilized for filling microfractures and permeating micro-gaps as well as a structural bonding agent with a long pot life and resistance to moisture during application [10].

The composite is reinforced with E-glass biaxial 0:90 fiberglass fabric. The E-glass basis is textile and consists of silica, alumina, boron, and calcium and consists of a low content of oils and minerals, that are inorganic carbon-based materials [11].

Date pits were gathered, washed with distilled water to eliminate date residue and dirt, then air-dried at room temperature. Thereafter, the date pits powder (DP) was finely milled utilizing an electrical milling device with a steel blade at 1800 rpm rotational speed. The powder of the milled date pits was acquired via a sieve with an aperture diameter of 200  $\mu\text{m}$ . In order to defat the date pits powder (DP), weigh 50 grams and apply a 2% alkaline solution (NaOH) and dissolve 2 grams in 100 ml of distilled water in a glass or plastic beaker. The powder was dispersed in the solution with continuous stirring for 3 hours at room temperature, stripping impurities, some lignin, and enhancing OH groups on the surface. Purifier the powder and wash it repeatedly with distilled water to the extent that the  $\text{pH} \approx 7$  to avoid chemically interacting with the epoxy later. Then the powder was heat-dried in an electrical oven at 65 °C.






















### 2.2 Composite Preparation and Testing

The composite materials were prepared by hand lay-up technique, fabricating a 5x5 cm glass plate-

designed mold with a thickness of 3 mm and a plastic substrate to assist separation of molds upon drying.

In the first step, the mold was cast from pure epoxy resin (ER) with hardener and deposited in a vacuum chamber to decrease bubbles and voids. Following this, it was dried at room temperature for 24 hours, at this point, the samples are prepared for cutting and testing. The second step involves reinforcing the epoxy resin (ER) with the fiberglass (FG) arranged in a single layer utilizing toothed wheels to guarantee homogeneous distribution and absorption of the epoxy resin (ER) through the fiberglass. The next step, Epoxy reinforced with glass fiber (EG) was filled with date pits powder (DP) to form glass fiber-reinforced epoxy resin filled with date pit powder (EGDP) according to the weight ratios of (0,5, 10, 15, 20, and 25%). Prepared by pure ER, it was filled with date pits (DP) and combined in an electric mixing device at room temperature for 10 minutes at 50–150 rpm. The filled epoxy was positioned in an ultrasonic device up to the point when all the combine were integrated as well as in a vacuum chamber. Finally, EP was cast in the mold and reinforced with glass fiber (EG) arranged in a single layer utilizing toothed at room temperature. Composite materials were prepared to according (ASTM) for mechanical and physical testing using (CNC) machine with a drill in a rotating head for shaping various solid materials as shown in Table 1.

Table 1: The composite was produced in the following proportions.

Composite materials	Tensile Tests	Bending and Impact Test	Dielectric Conductivity
100%ER			
90%ER-10 %GF= EG			
95%EG: 5% DP			
90% EG: 10% DP			
85% EG: 15% DP			
80% EG: 20% DP			
75% EG: 25% DP			

### 2.3 Mechanical Tests

Tensile tests of composite materials according to (ASTM D3039) were utilized by (Zwick/Roell Z010), Germany. The drawing speed (5 mm/min) and tensile load (15 Kg). The bending test (ASTM D790) was carried out on the previously used equipment when employing the 3-point bending technique at speed (0.5 mm/min). Charpy Impact tester (ASTM D6110) is composed mainly of a pendulum and energy gauge (Instron-Dynatup, USA) and time testing machines). Shore D hardness tester (ASTM D2240) by (Zwick-Roell, Germany), all tests performed at room temperature.

### 2.4 Physical Tests

Dielectric test specimens according to (ASTM D150) using the Parallel Plate Method were measured Dielectric Constant ( $\epsilon$ ), Dissipation Factor ( $\tan \delta$ ) and A.C. electrical conductivity, all tests were performed at room temperature. Water absorption of plastics test (ASTM D570) through, dry weight samples to mg accuracy balance. immersed in distilled water at 23°C. Carefully clean surface from water with a tissue and was weigh at: 24 hours, 48 hours, 7 days and 14 days then was calculating the absorption percentage.

## 3 RESULTS AND DISCUSSION

### 3.1 Tensile Test

The variation in modulus of elasticity and tensile strength with reinforcing and filling with ER as shown in Figure 1 and Table 2.

Ultimate tensile strength specifies the capability of composite materials to prevent failure when exposed to longitudinal tensile stress [12]. The observed tensile strength results indicated the highest values at a low weight ratio of EGDP composite, particularly at the maximum observed increase  $DP \leq 15\%$ , as a result of the strengthening of bonds and filling of voids between the interfaced polymer network of EG and DP because it was processed from oils and organic matter. Incorporating a proportion of  $DP \geq 20\%$  led to EG saturation, which caused a reduction in the mechanical and physical performance attributed to matrix saturation begins to cause low interfacial strength or defects [12].

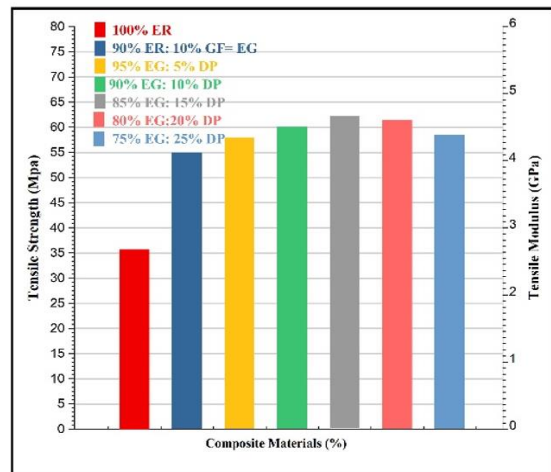


Figure 1: Tensile strengths of the different composite materials.

### 3.2 Bending Test

Bending strength values  $DP \leq 15\%$  were enhanced in reinforced composite materials due to glass fibers (GF) increasing the dynamic strength of the high structural resistance, carrying part of the load and transferring stresses coherently with the matrix. At this ratio, DP is partially well distributed in EG, increasing the interfacial roughness and mechanical interlocking. At  $DP \geq 20\%$ , powdered filler becomes too numerous in the matrix (agglomeration) caused weak disruption of matrix cohesion, an increased defects and amplified voids because of issues with fully saturating EG and weak interfacial bonding between the DP and EG as shown in Figure 2 and Table 2.

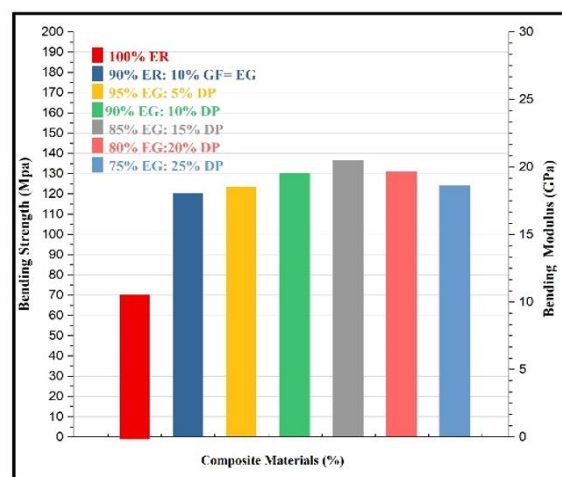


Figure 2: Bending strengths of the different composite materials.

Table 2: Mechanical properties of composite materials.

Composite Materials	100% ER	90% ER: 10% GF=EG	95% EG: 5% DP	90% EG: 10% DP	85% EG: 15% DP	80% EG: 20% DP	75% EG: 25% DP
Tensile strengths (MPa)	35,7	55	58,1	60	63	61,6	58,6
modulus (Gpa)	2,7	4,22	4,56	4,61	4,7	4,65	4,35
flexural strength (Mpa)	70,5	120,8	124,2	129,8	137,5	131,1	125,1
flexural modulus (Gpa)	10,12	18,1	18,7	19,7	21,3	19,8	18,5
impact resistance (J/m)	70,76	99,6	110,1	120,68	130	123,8	116,2
energy absorption (J)	2,18	2,98	3,31	3,45	3,83	3,61	3,4
shore D hardness	75,4	78,7	79,1	79,98	80,7	79,6	78,7

### 3.3 Impact Test

It was observed in this test that the impact strength values improved at  $DP \leq 15\%$  due to strengthened stress distribution and impact energy absorption by EGDP, on the other hand the decrease in impact strength at  $DP \geq 20\%$  was due to EG saturation with DP, void generation, and weak adhesion, leading to a reduction in the potential to absorb shock as shown in Figure 3 and Table 2.

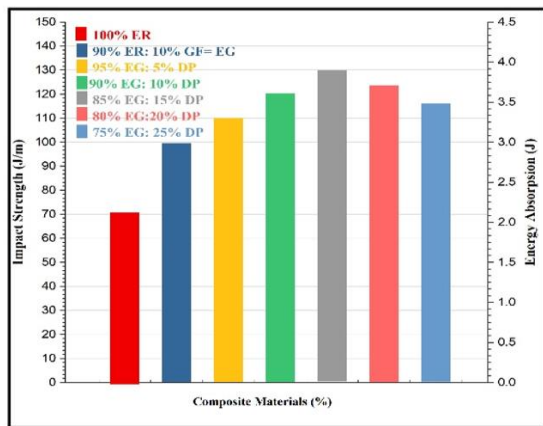


Figure 3: Impact strengths of the different composite materials.

### 3.4 Shore D Hardness Test

The increase in EGDP hardness at  $DP \leq 15\%$  was due to improved properties Interfacial of adhesion and distribution of EG and DP, while the decrease at  $DP \geq 20\%$  caused by the EG being fully saturated with DP, agglomeration and voids generation, and reduced interfacial strength, leading to a decrease in the composite's ability to resist surface deformation as shown in Figure 4 and Table 2.

### 3.5 Dielectric Test

Properties of composite materials reinforced with EG and DP under electrical properties testing indicated an increased value at  $DP \leq 15\%$  leading to improved DP and distribution within GE, enhancing the effective interface for interaction between the EG and DP. This enhances localized electrical polarization, raising the dielectric constant  $\epsilon$  as shown in Figure 5.

The contributing factor was due to the homogeneous distribution of DP in the absence of the creation of agglomerates or voids.  $\tan \delta$  was increased slightly due to the interaction of DP with the EG and enhanced local polarization losses as shown in Figure 6.

Improved A.C. electrical conductivity at  $DP \leq 15\%$ : as a result of homogeneous distribution of DP and GF and improved interface with ER. Declined conductivity at  $DP \geq 20\%$ : caused by DP agglomeration and increased void formation, which impedes the electrical current transport as shown in Figure 7.

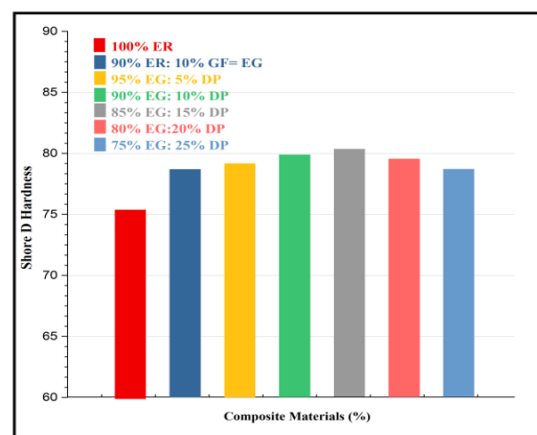


Figure 4: Shore Hardness of the different composite materials.

### 3.6 Water Absorption Test

The Figure 8 shows the water absorption properties of the composite materials and shows ratios reduction at  $DP \leq 15\%$  as a result of G, followed by an increase at  $DP \geq 20\%$  because of the hydrophilicity of DP, despite the fact that NaOH treatment slightly decreased the water absorption, the interface between the G and the matrix was improved the durability.

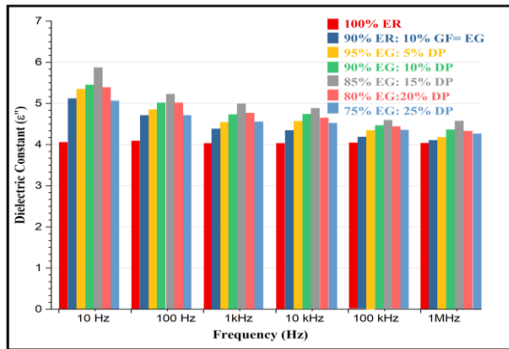


Figure 5: Dielectric constant of the different composite materials.

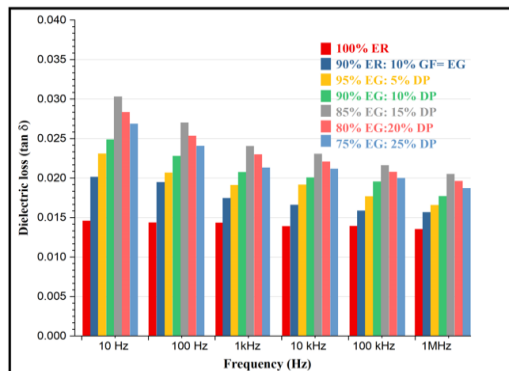


Figure 6: Dielectric loss of the different composite materials.

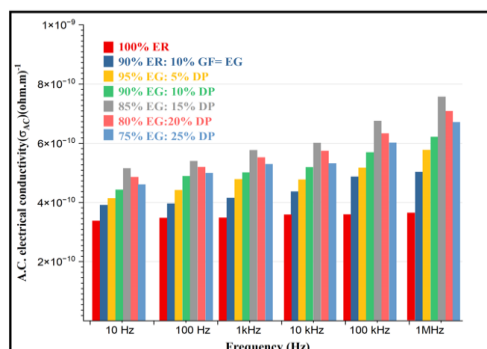


Figure 7: A.C. electrical conductivity of the different composite materials.

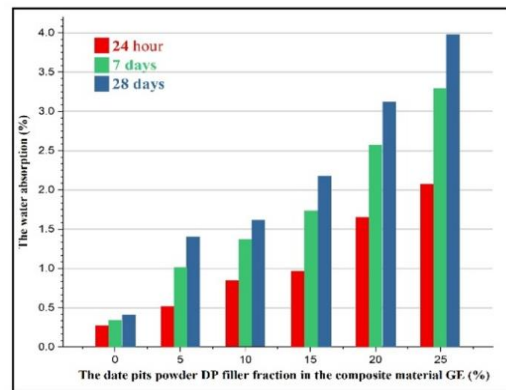


Figure 8: Water absorption test of the different composite materials.

## 4 CONCLUSIONS

This Research centered on enhancing eco-friendly hybrid composite materials by exploring the influence of loading Date Palm powder (DP) with weight ratios: 5%, 10%, 15%, 20%, and 25% wt. into an Epoxy resin/ fiber Glass (EG) matrix significantly influenced the mechanical and physical performance of the prepared samples. The properties showed a progressive change with rising DP up until a filler content of 15%, with the maximum values observed in: Tensile strength and modulus (63 Mpa, 4.7 Gpa), flexural strength and modulus values (137.5 Mpa, 21.3 Gpa), the impact resistance and energy absorption values (130 J/m, 3.83 J) and shore D hardness result (80.7). The electrical properties showed an increase at  $DP \leq 15\%$  in dielectric constant, dielectric loss and A.C. electrical conductivity, accompanied by a relative decrease in water absorption. This increase resulted from the well-dispersed state of DP within the EG matrix and the improved interfacial bonding between the DP filler, E-glass fibers, and epoxy resin.

Nevertheless, rising DP content to  $DP \geq 20\%$  resulted in a reduction values observed in mechanical and physical properties owing to the creation of voids and agglomerates in the composite structure and inhomogeneous distribution. This resulted in a decline in mechanical characterization and a rising in water absorption. Therefore, it may be concluded that the most effective addition of DP is 15%, because it reaches the optimal balance between improving mechanical and physical features and decreasing structural defects in the composite. These results indicate that this hybrid composite materials is a potential option for eco-efficient engineering applications entailing lightweight and electrical

insulation material properties. Further research may study the influence of chemical applications on DP surfaces to elevate compatibility at higher loadings, in addition to study the thermostability of these composite materials.

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