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study of some mechanical and thermal properties for a composite material of a polymeric basis reinforced by natural material shells

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ABSTRACT

This study includes the possibility of using the agricultural residues shell (walnut and pistachio) as a filler in epoxy resins as an alternative to wood and plastic based ingredients. specimens of composite materials were prepared by using hand lay-up method. These specimens were represented by two groups of composite materials that consist of epoxy resin as a material matrix reinforced with walnut shell powder once, and pistachio shell powder again with different weight ratios (11%, 15% and 19%). Mechanical tests (impact, hardness, bending) and some physical tests (thermal conductivity, absorption) were carried out. All the results were done at the temperature of the lab. The results of the specimens tests prepared showed an improvement in the impact strength when adding the minutes of the pistachio shell by ratio 15% where it reached (12.9 KJ/m^2), while it saw a decrease in the composite reinforced by walnut shell powder at the same ratio (6.3 KJ/m^2), The hardness of the composites also improved at the addition ratio 19% where it reached (83.2 N/m^2) in the composites reinforced by the minutes of the walnut shell and (81.9 N/m^2) in the composites reinforced by minutes of pistachio shell, Bending resistance also increased to the highest value at the addition ratio 19% to (56.82 N/mm^2) in the composites reinforced by the minutes of the walnut shell and (54.4 N/mm^2) in the composites reinforced by the minutes of the pistachio shell..On the other hand, physical measurement showed a slight increase in the values of thermal conductivity and absorption. The results indicate that the composite material reinforced with pistachio shell powder have higher values in impact, bending and thermal conductivity tests and lower values for hardness and water absorption tests when compared with composite material reinforced with walnut shell powder.

1- Introduction

Composite materials are material that resulting from mixing two or more different materials physically and chemically in order to obtain a new material characterized by good physical and mechanical properties. The composites have many properties and advantages such as light weight, hardness, bending resistance, and low thermal expansion coefficient, which have made them suitable for use in many complex and advanced applications [1]. Composite Material consists of two main parts: Matrix Material, which includes materials (metal, ceramic, polymeric) and Reinforcement Material, which are different shapes, may be Fibers, powders, Flakes, Particles, Fillers or Wool According to the application to be done. The reinforcement material improves the mechanical properties of durability, hardness and Stiffness of the matrix material provided that they form a strong bond between them [2].Epoxy resin is used as a matrix material in many composites because of its little contraction when processed and has good adhesion, but its main Defect is brittleness. Therefore, fillers must be added to it to provide the durability and strength required. Many researchers have stressed that adding fillers of various kinds improves the mechanical properties of epoxy resin [3,4].There is currently a global interest in the manufacture of environmentally friendly composite materials, which has prompted researchers to use natural materials from agricultural residues as an alternative to plastic and chemical materials to manufacture high-performance composites that can be recycled, These natural materials are characterized at their low cost ,availability in large quantities and the ability to decompose in nature [5,6].The main problem in the use of these natural materials as fillers in polymeric composites is their ability to absorb water which may cause a decrease in mechanical properties after swelling. The adhesion between the filler material and the matrix material can be increased and water absorption reduced by some chemical treatments [7].The researcher stated that the addition of nano silica carbide can reduce water absorption and improve the mechanical properties of polymeric composite [8].The current study aims to recycle walnut and pistachio shell and the possibility of using them as fillers in polymers. Walnuts are agricultural crops that are grown in moderate regions of the world such as China, USA, Iran, Turkey and northern Iraq and are considered from edible nuts. Walnut shell Make up about 67% of the total weight of the fruit, so large amounts of these shells are left yearly [9,10]. walnut shell powder is used as an effective abrasive in polishing and cleaning of solid materials such as metals and hard plastics. It is also used in low applications such as burning and fertilizers in addition to using it as a filler material in polymers [11]. Pistachio is also edible crops, It is heavily cultivated in the Middle East, the United States and the Mediterranean countries, and Turkey is one of the largest producers of pistachios [12]. Natural material particle have been used as reinforcement materials by many researchers. (Khantwal) studied a composite material, reinforced by particle of walnut shell at different weight ratio. And he mentioned that the addition of the particles of the walnut shell had a big effect on both tensile strength and the coefficient of flexibility and elongation, He also mentioned that the size of particles of the added walnut shell may differ in reinforcement the mechanical properties of the composites[13]. (Chandramohan) worked on developing a bio-polymeric composite consisting of an epoxy resin reinforced with particle of shells hybrid natural materials (walnut, coconut, rice) and studying its mechanical and physical properties, he concluded that the composite, which contains the particles of the shell (walnut, coconut) has improved its mechanical and physical properties compared to the composite containing (walnut, rice) and (coconut, rice) [14].(Sandeep) studied the impact behavior of polymer composites polymeric reinforced pine needle fiber/pistachio shell filler and the study showed an improvement in impact strength Then, he tested the composites in different environmental conditions (water, gasoline, kerosene) and noted that there was a decrease in the impact strength compared to the first case [15].

2- Material and experimental details

2-1 Preparation samples :-

2-1-1 Material matrix

Epoxy Sikadur 52 LP has been used as a matrix material and is characterized as a transparent liquid with a density of approximately (1.1 g /cm^3) and low viscosity which allows a good mixing with the reinforced material and achieving a complete homogeneity, It is also little contraction and has good adhesion and is able to be processed and transformed into a solid state by adding the hardener. The hardener added to the epoxy resin in a ratio of (1: 2), meaning that every 1gram of the hardener is corresponds by 2gram of the epoxy resin, The interaction between them occurs at the temperature of the laboratory.

2-1-2 walnut shell powder and pistachio

In this research, walnut shell and pistachio were used as a filler in polymer. Collected and cleaned well and then cut into small pieces by hand crusher and then milled using a German-origin electric mill (sielver crest) and then sieved to obtain particles size equal or less than 200µm. Walnut shell and pistachio are renewable material that we can get them as agricultural products. The powder and raw walnut shell and pistachio are shown in Fig. 1. The chemical composition of walnut shell and pistachio are presented in Table 1.

Fig. 1: a. pistachio shell b. pistachio shell powder c. walnut shell d. walnut shell powder

Table 1: Chemical composition with some physical properties for walnut shell and pistachio [16,17].

Parameters	Values	
	Walnut shell	Pistachio shell
Ash content(%)	3.1	0.8
Moisture content(%)	3.8	4.92
Pore volume(ml g^{-1})	0.67	0.71
Density(g cm^3)	1.1	1.4
Lignin(%)	20-30	13.5
Cellulose(%)	40-60	42

2-2 specimens preparation

All specimens were prepared using hand lay-up method by mixing the epoxy resin with hardener in a ratio (1:2), meaning that every (1 part) of the hardener is corresponds by (2 part) of the epoxy resin, Then is added the walnut shell powder and pistachio according to the ratio of the addition (11%, 15% and 19%). All these materials are mixed in a ceramic container for a period of (5:10) minutes in order for the mixture to be well homogeneous, then this mixture poured into the molds and leave for 24 hours to harden. After that the specimens are taken out and treated thermally in the thermal oven and at a temperature of 50 ^{0}C and for a time of 60 minutes in order to get rid of bubbles and internal stress, and then comes the process of cutting, smoothing and preparing of all specimens according to specifications (ASTM).

2-3 Impact Test

Charpy impact test machine was used (Testing Machines Inc. AMITYVILLE. New York) to test prepared specimens with dimensions 55mm x 10mm, according to ISO 179/92. All specimens were tested at laboratory temperature. Impact strength is defined as the amount of energy required to fracture a sample through the unit area, and was calculated using the relation [18].

$$I.S = \frac{E_F}{A} \ldots\ldots\ldots\ldots..(1)$$

where

I.S : Impact strength (KJ/m^2) , E_F : fracture energy (J) and A: Sample cross-sectional area (mm^2).

The specimens before and after the testing are shown in fig.2.

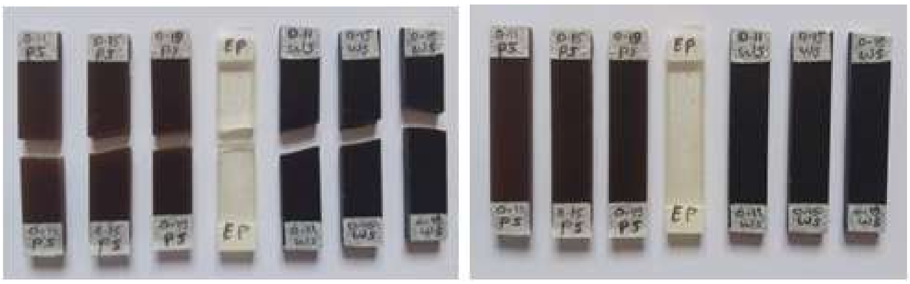

Fig. 2: specimens before and after the testing

2-4 Hardness test

The hardness of specimens prepared was measured by (TH210 Shore-D hardness) of Italian-origin, The average was taken for three readings to get a more accurate result. The hardness can be defined as resistance to the surface of the material on scratching or penetration.

2-3 bending Tests

A three-point device was used to measure the bending strength of prepared samples, The test technique depends on fixing the sample on two cushions and the load is shed at a point in the middle of the sample until the failure of the sample occurs. The Flexural strength can be calculated from the following relation [19].

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

Where

F.S: The Flexural strength (Mpa) ,P: Maximum load (N), L: Distance between two cushions (mm),b: width the sample (mm) and d: thickness the sample (mm).

The specimens before and after the testing are shown in fig.3.

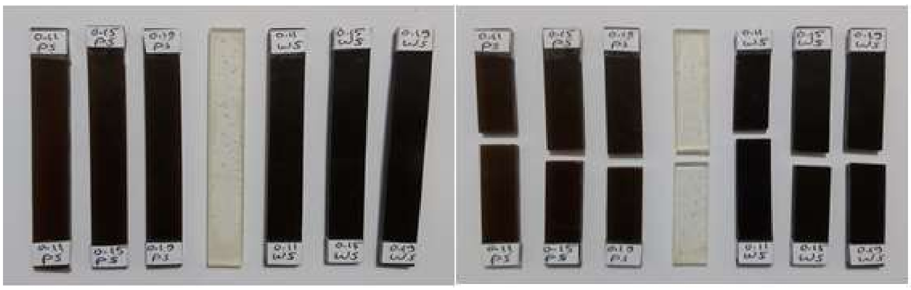

Fig. 3: specimens before and after the testing

2-4 thermal conductivity test

A Lee's-disk method was used to find the thermal conductivity of prepared composites. This method is usually used for bad materials conductivity. According to the following relation [18].

$$K\left(\frac{T_B-T_A}{d_S}\right)=e\left[T_A+\frac{2}{r}\left(d_A+\frac{1}{4}d_S\right)T_A+\frac{1}{2r}d_S T_B\right] \quad \ldots\ldots(3)$$

$$IV=\pi\ r^2e(T_A+T_B)+2\pi re\left[d_AT_A+d_S\frac{1}{2}(T_A+T_B)+d_BT_B+d_CT_C\right]$$

where

e: Thermal energy passing through the disk space unit per second ($w/m^2.k$), T_C, T_B, T_A: The disc temperature A, B and C respectively ($^{\circ}C$), d_A, d_B, d_C: Disk thickness = 12.5mm, d_S: Sample thickness (mm), I: The current passing through the circle (Ampere), V: The voltages supplied to the circuit (volt) and r: Disk radius (mm).

Thermal conductivity test specimens are shown in fig.4.

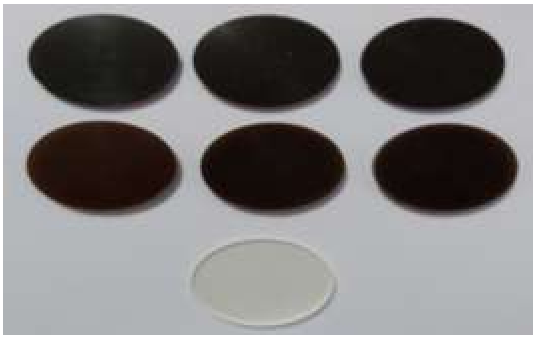

Fig. 4: Thermal conductivity test specimens

2-7 Water Absorption test

The method of frequent immersion in water has been used for long periods of time to determine the absorption behavior of prepared sample. The test technique is summarized by the weight of all samples before and after immersion every 3 days up to 12 days. Profit can be calculated in mass from the following relation [20].

$$\text{Weight Gain }\% = \frac{M_2-M_1}{M_1}\times 100 \quad ....(5)$$

where

M_1: Mass the sample before immersion(g) and M_2: Mass the sample after immersion(g).

3- Results and Discussion

3-1 Effect of Walnut and Pistachio shell Particles Content on impact Properties

Figures (5,6) show the results of the impact test. The addition of pistachio shell powder led to improve the impact strength when compared to the composites containing walnut shell powder. Increased impact strength is due to the possession of the additive reinforced material good resistance to impact, which in turn hinders the progress and spread of cracks, It was noted that the highest resistance to impact was in the composites reinforced particle the pistachio shell by 15% to 12.9 KJ/m^2, but when the added content of pistachio crust powder increases, it reduces the ability of the composite material to absorb the impact force. Reduced impact strength may be due to poor humidification of particles due to low epoxy resin content , It is consistent with the researcher's findings [20].

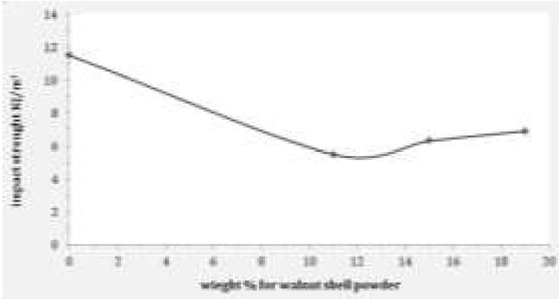

Fig. 5: Impact strength and absorbed energy versus Walnut shell content

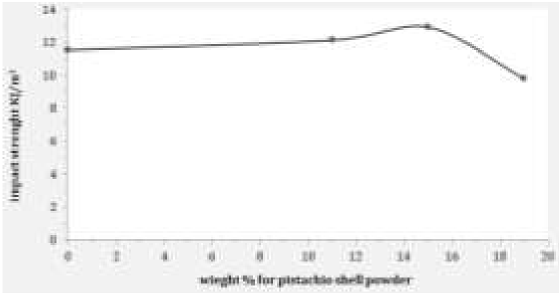

Fig.6: Impact strength and absorbed energy versus Pistachio shell content

3-2 Effect of Walnut and Pistachio shell Particle Content on Hardness Properties

From figures (7,8) it can be noted that the addition of reinforced particles (walnut, pistachio) has improved the hardness of the resulting composites compared to the unreinforced epoxy resin. It can also be noted that the composites reinforced by particle of walnut shell, have a higher hardness (83.2 N/m^2) when compared with the composites reinforced by the pistachio shell particle where they reached (81.9 N/m^2) while they were less valuable for hardness (72.3 N/m^2) in unreinforced epoxy resin. The explanation of this is attributed to the fact that the particles of the reinforcement material worked to fill the gaps and voids that arose during the process of manual molding i.e. that there is a characteristic relationship between the matrix material and the reinforcement particles, which leads to increased stacking and good tangle between the components of the composites material and as a result the movement of molecules decreases and polymer chains, thus increasing the resistance of the material to stitches and deformation in addition to the good spread for reinforced particles, It is consistent with the researcher's findings [21].

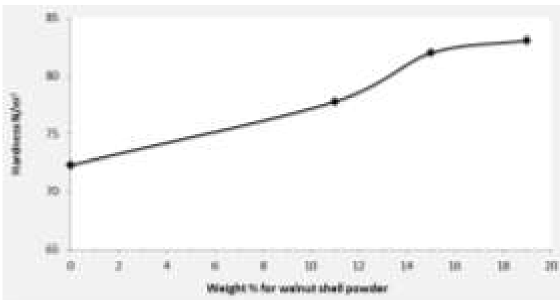

Fig. 7: walnut shell particle content versus hardness

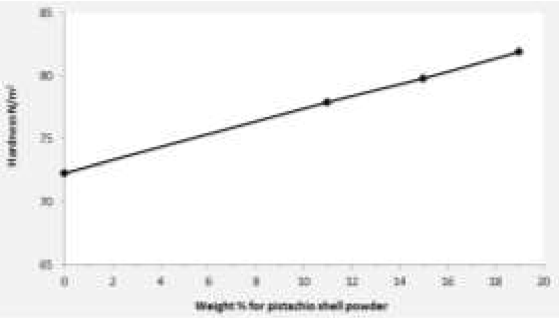

Fig. 8: Pistachio shell particle content versus hardness

3-3 Effect of Walnut and Pistachio shell Particle Content on Flexural Properties

Figures (9,10) show the addition of walnut shell particles to the matrix material has improved Flexural strength compared to the composites reinforced by the particles of the pistachio shell, Where the highest value in the composites reinforced by pistachio shell particles was at the ratio 19% It reached 54.4 N /mm^2, While 61.51 N/mm^2 was in the composites reinforced of the pistachio shell particles. This is due to the regular distribution of reinforcement particles where they fill in the blanks that can be formed during the process of manufacturing the composite material, which leads to increased strength of bonding and cohesion between the material reinforced material and the matrix material, and this in turn has had a great impact in giving the composites high values to resist Bending, Moreover the high rigidity of these crusts under the effect of bending stress. This subject was studied and supported by researchers [22,23].

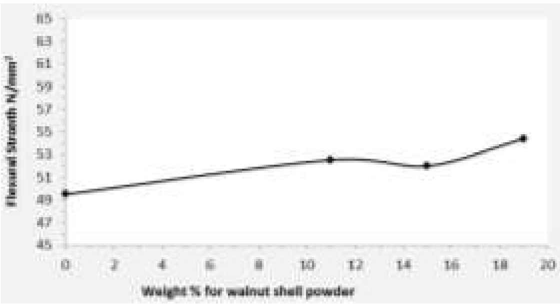

Fig. 9: walnut shell particle content versus flexural strength

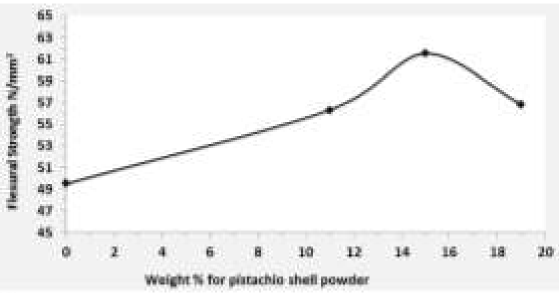

Fig. 10: Pistachio shell particle content versus flexural strength

3-4 Effect of WS and PS Particle Content on Thermal Conductivity Properties

From Figures (11,12) we note that the addition of reinforced material to epoxy resin has slightly improved the values of thermal conductivity. Although the increase was slight, there is a change in the values of conductivity. The explanation of this is that the reinforcement particles have a higher thermal connection than epoxy resin when comparing between them, were the values of thermal conductivity depend on the type of reinforcement material and its ability to conductivity. It is consistent with the results of the researcher [24].

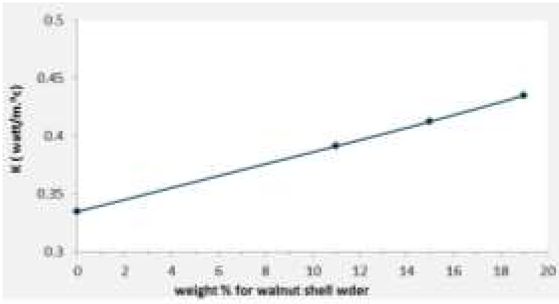

Fig. 11: walnut shell particle content versus thermal conductivity

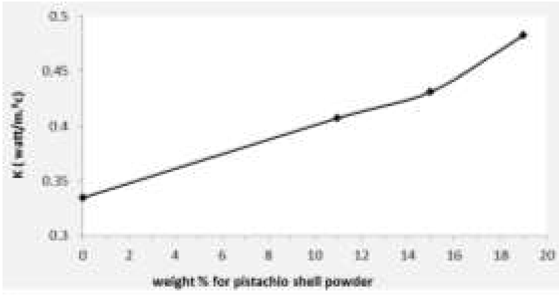

Fig. 12: Pistachio shell particle content versus thermal conductivity

3-5 Effect of Walnut and Pistachio shell Particle Content on Absorption Properties

From the figures (13,14) we note that the composite material consisting of epoxy reinforced by particles of walnut shell recorded the highest absorption rate at the rate of addition 19% compared to the composites reinforced by the particles of the pistachio shell, While the lowest absorption rate was in unreinforced epoxy, This means that the reinforcement particles had a significant effect on the absorption process and increased sample weight, although the absorption rate is very low over time. because water is a plasticizing factor for the resinous material, Which is consistent with the results of the researchers [25-27].

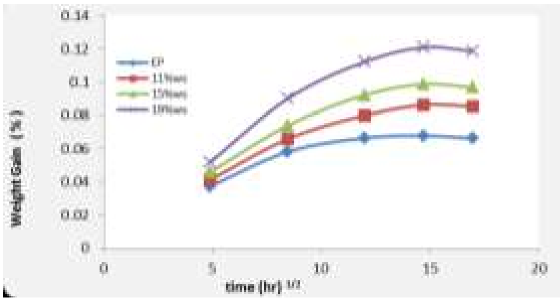

Fig. 13: The relation between the gain in absorbance and the square root of time for walnut powder samples

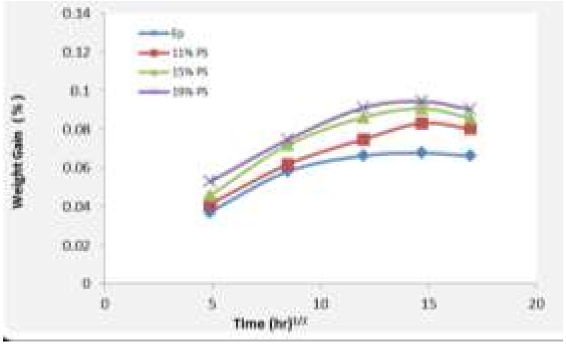

Fig. 14: The relation between the gain in absorbance and the square root of time for pistachio powder samples

4- Conclusions

After mechanical and physical tests carried out on the prepared composites, the following conclusions were reached in this study

1- The results of the impact strength test showed that the addition of pistachio shell powder led to an improvement in the strength of the impact, while decreased when the powder of walnut shell, but began to improve with the increase of weight ratios to add.

2- The addition of both reinforced materials, walnut shell powder and pistachios, to epoxy resin has increased both hardness and Flexural strength.

3- As for the physical properties, they have seen a slight increase in both thermal conductivity, absorption when adding reinforcement powders.

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دراسة بعض الخصائص الميكانيكية والحرارية لمادة متراكبة ذات اساس بوليمري مقواة بقشور مواد طبيعية

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قسم الفيزياء ، كلية التربية للعلوم الصرفة ، جامعة تكريت ، تكريت ، العراق

الملخص

تضمنت هذه الدراسة إمكانية استخدام قشور المخلفات الزراعية (الجوز والفستق) كمواد حشو في راتنج الايبوكسي بديلا للمكونات التي تعتمد على الخشب والبلاستيك. تم تحضير عينات المواد المتراكبة بطريقة القولبة اليدوية. وتمثلت هذه العينات بمجموعتين من المواد المتراكبة التي تتكون من راتنج الإيبوكسي كمادة اساس مقواة بمسحوق قشرة الجوز مرة، ومسحوق قشرة الفستق مرة أخرى وبنسب وزنية مختلفة (11 ٪ ، 15 ٪ ، 19 ٪). واجريت الفحوصات الميكانيكية (الصدمة، الصلابة، الانحناء) وبعض الفحوصات الفيزيائية (التوصيل الحراري، الامتصاص). وتمت الفحوصات جميعها في درجة حرارة المختبر. أظهرت نتائج اختبارات العينات التي تم إعدادها تحسنًا في متانة الصدمة عند اضافة دقائق قشرة الفستق بنسبة 15% حيث بلغت ($12.9\ KJ/m^2$)، بينما شهدت انخفاضًا في المركب المدعم بمسحوق قشرة الجوز بنفس النسبة اذ بلغت ($6.3\ KJ/m^2$)، كما تحسنت صلادة المتراكبات عند نسبة الاضافة 19% اذ بلغت ($83.2\ N/m^2$) في المتراكبات المقواة بدقائق قشرة الجوز و ($81.9\ N/m^2$) في المتراكبات المقواة بدقائق قشرة الفستق، وكذلك ارتفعت مقاومة الانحناء الى اعلى قيمة عند نسبة الاضافة 19% اذ بلغت ($56.82\ N/mm^2$) في المتراكبات المقواة بدقائق قشرة الجوز و ($54.4\ N/mm^2$) في المتراكبات المقواة بدقائق قشرة الفستق.. من ناحية أخرى أظهرت الاختبارات الفيزيائية زيادة طفيفة في قيم التوصيلية الحرارية والامتصاصية. تشير النتائج إلى أن المواد المركبة المقواة بمسحوق قشرة الفستق لها قيم أعلى في اختبارات الانحناء والموصلية الحرارية وقيم أقل لاختبارات الصلابة وامتصاص الماء عند مقارنتها بالمواد المركبة المقواة بمسحوق قشرة الجوز.