THE INFLUENCE OF LOW COST FILLER ON SOME MECHANICAL AND PHYSICAL PROPERTIES OF A POLYMER MATRIX COMPOSITE

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Abstract

Experimental study has been done in this research to explain the influence of low cost fillers contents on the mechanical and physical properties of unsaturated polyester resin composite with different weight fraction. The effect of three particles; Baby powder particles including MgO, Fire extinguisher particles including CaCO3 and chalk particles including SiO_2 with weight fraction of (5%, 10%, 15%)Wf% added to polyester matrix on the wear rate under dry sliding conditions, hardness, thermal conductivity, and water absorption has been investigated. The wear rate was measured according to ASTM G99-05 standard with pin on disc machine, hardness measured according to ASTM D-2240 Shore D hardness test, Lee's disc technique used to measure thermal conductivity, while water absorption measured according to ASTM D 570 standard. The results shows that the addition of fillers leads to increasing the wear resistance, hardness and water absorption and decrease the thermal conductivity with the increasing in reinforcement material weight fraction. while, the wear resistance decreasing with increase in applied load. The results appeared that the addition of particles to polyester resin leads to increase in all the mechanical and physical properties tested in this research better than polyester specimen only and MgO-polyester composite given the best wear resistance.

Keywords: polyester composite; MgO, SiO2, CaCO3; wear behavior, hardness…etc.

دراسة تاثير الاضافات منخفضة الكلفة على بعض الخواص الميكانيكية والفيزيائية لمادة متراكبة بوليمرية

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الخلاصة

في هذا البحث تمت دراسة تأثير الحشوات منخفضة الكلفة على الخواص الميكانيكية والفيزيائية لراتنج البوليستير الغير مشبع المقواة بالدقائق عمليا عند كسور وزنية مختلفة. أن مواد التدعيم المستخدمة في هذا البحث كانت هي عبارة عن دقائق محضرة من مواد بسيطة منخفضة الكلفة وهي: دقائق بودرة الاطفال الحاوية على اوكسيد المغنسيوم MgO ، دقائق مطفاءة الحريق الحاوية كاربونات الكالسيوم $CaCO_3$ ، ودقائق مادة الطباشير الحاوية على اوكسيد السيليكون SiO_2 وبحجم حبيبي 10µm وبكسور وزنية (٥%، ١٠، ١٥%) لدراسة سلوك البليان والصلادة والموصلية الحرارية وامتصاصية الماء عند اضافتها الى مادة البوليستر الغير مشبع. حيث تم دراسة مقاومة البليان وفقا للمواصفة ASTM G99-05 باستعمال جهاز المسمار مع القرص الدوار وقياس الصلادة وفقا للمواصفة ASTM D-2240. تم قياس الموصلية الحرارية بأستخدام قرص لي بينما تم قياس امتصاصية الماء وفقا للمواصفة ASTM D 570.وقد اظهرت النتائج ان اضافة مواد التدعيم ادت الى زيادة مقاومة البليان والصلادة وامتصاصية الماء وخفض الموصلية الحرارية مع زيادة الكسر الوزني لمواد التدعيم وان زيادة الحمل المسلط خلال اختبار البليان اى الى زيادة معدل البلى المقاس. واضهرت النتائج ايضاً ان جميع مواد التدعيم المضافة للبوليستر

اعطت نتائج افضل من عينات البوليستر الغير مدعم وان افضل نسبة تدعيم كانت هي ١٥% من دقائق اوكسيد المغنسيوم عن اضافتة الى راتنج الابوليستر.

1. Introduction

Polymeric composites have become main part of manufacturing application due to their unique thermal and mechanical properties apart from their easy process ability and low cost. Such materials are good candidates to form a special class of engineering tribo- materials due to their unique properties such as wear resistance, impact resistance, corrosion resistance and ease of fabrication. They are utilized in numerous applications including seals, cutting tools, bearings and artificial prosthetic joints. For such applications and others, polymer matrix must with stand high mechanical and tribological loads, so fillers, fibers or particles and added to enhance its properties **[1].**

Polymer composite has been widely used to substitute the conventional metals and ceramics in microelectronic bundling, coating, aerospace, automotive and biomedical applications. This is fundamentally because of their unique strength, lightness, versatility, ease of treatment and low cost. By adding of reinforcement particles, the tribological properties of polymers are in general enhancement **[2].**

The using of micro particles as a reinforcement material in polymers composite has attracted extra attentions. The very high specific surface area eases creating a mighty amount of interphase in composite and a strong interaction between the particles and the matrix. Particles can enhancement the mechanical and physical properties of polymers. Some of these particles it will used to reinforce polymers are (SiO_2, MgO and SiC) due to its rigidity and high stability **[3]**.

Wear is defining as harm in a solid surface, generally including gradual loss of materials, caused by relative motion between two surfaces. The general kinds of wear are abrasive, fretting, erosion, adhesive and fatigue wear, which are usually seen in practical cases. The ingrained scarcity of polymers could be change successfully by using different special particles **[4].**

In order to obtain the wear resistance, hardness, water absorption and dielectric strength many researchers modified polymers using different fillers. Briscoe et al., notified that the wear rate of high density polyethylene (HDPE) was decreased with the addition of inorganic particles, like CuO and Pb_3O_4 **[5]**. Husam .A. Kareem studied the mechanical properties of polyester resin reinforced by nickel powder, the results showed improved material toughness, fracture toughness, compression strength and wear resistance with the increasing of volume fraction and using of (10µm) particle size. The result also showed that the wear rate increase with the increasing of load and temperature **[6].** Haqi I.Gattea, study the effect of Magnesium oxide (MgO) with (5 µm) particle size with different Weight percentages (5%,15%,25%) was added to conbextra epoxy (EP-10) resin and measured the changing in thermal insulation to this resin. the results show improved thermal insulation of the resin by reduced in thermal conductivity coefficient value after oxide addition , and the value of thermal insulation will increased with increasing of additive percentage of magnesium oxide **[7].**

Amar .J. Bader et.al, prepared polyester matrix composites reinforced with short glass fiber and reinforced with glass fiber and Al_2O_3 particles with different weight fractions (3, 5, and 7 wt% Al_2O_3) and study some of mechanical properties to the prepared composites. The results shows the mechanical properties improve with increasing weight fraction **[8].**

Ali Al-Mosawi, study the mechanical and thermal properties of epoxy (EP-10) resin reinforced by Magnesium oxide (MgO) with (5 µm) particle size with different Weight percentages (10%,20%,30%) the results show improved thermal insulation of the resin by reduced in thermal conductivity coefficient value and improvement in impact strength, tensile strength, and compression strength after oxide addition **[9].**

Ibtihal et al., studying the effect of 10µm (granite, perlite and $CaCO_3$) particles used as a reinforcement material for carbon fiber-epoxy composite on wear behavior, and they observed that the adding of particles leads to increase the wear resistance **[10].**

In this work a new polymer composite are prepared to investigate the wear properties, hardness, water absorption and thermal conductivity of polyester composite reinforced with low cost materials; Baby powder particles including MgO, Fire extinguisher particles including CaCO3 and chalk particles including SiO2 with weight fraction of (5%, 10%, 15%)Wf%.

2. Experimental details

2.1 Materials

Baby powder particles including MgO, Fire extinguisher particles including CaCO3 and chalk particles including SiO2 with grain size (10 μm) and weight fraction (5%,10%, and 15%) used as a reinforcement material for polyester resin. Unsaturated polyester used as a matrix material produced by (SIR). It is in liquid state at room temperature but after adding the hardener will change to solid state. The hardener used to this purpose Methyl Ethyl Keton Peroxide with mixing ratio 1:50 hardener to polyester resin at room temperature. The properties of the matrix material shown in **Table.1.**

2.2 Specimens Preparation

Hand layup technique was used in this research to prepare the specimens. Glass mould used to casting the composite material specimens with dimension of (200, 150, and 10) mm as shown in **Fig.1**. The inner face of the mould was covered with a layer of Vaseline to ensure no-adhesion between the polymeric material and the mould. The composite material is prepared by mixing the polyester resin with the hardener in (3:1) ratio at room temperature with a very slow mixing by using glass rod for (15min) until the polymer material will be homogenous, 10μm particulate fillers with 5, 10, and 15 wf% of MgO, SiO2 and CaCO**3** added to polyester resin respectively and the mixing continuous until it becomes homogenous, After (2min) the mixing was completed, To prevent air from including inside the specimens we should poured the mixing from one side of the mould and slowly, After 24 hours the solidification process is completed for all moulds and we can released the casts from the moulds.

3. Mechanical and physical test

3.1 wear test

According to ASTM G99-05 wear test standard the casts are cut with dimensions as shown in **Fig.2.**to prepared wear test specimens. Pin-on-Dick test instrument in Applied Science Deportment/university of technology shown in the **Fig.3** was used to fulfillment the wear test. The effect of different weight fraction and loading, on wear rate was studied according to Eq. (1). The steel disc have hardness of (385 HV), speed of (200 r.p.m), and rotating radius of (90 mm). Wear tests were carried with sliding time about (900s) and loads ranging from (10-30 N). By using sensitive balance weight with an accuracy of (10^{-4} g) the initial weight of all the specimens was measured. After the test ending all the specimens weighed again to calculate the weight loss due to wear. The variance in weight measured before and after tests gives full conception about wear behaviour of the composite specimen. To consider the volume wear rate using Eq. (1).

Wear rate (volume) (cm^3/m) = $\frac{W1-W2}{S*\rho}$ ………………………………………..… (1)

Where: W1: weight before testing (g), W2: weight after testing (g), ρ: density (g/cm^3) and S: sliding distance (m) calculated form Eq. (2).

$S=2\pi rnt$ ……………………………………………………………………… (2)

n = disc rotational speed, r.p.m, r = the distance from the center of the sample to the center of disc, m, t = time of testing, min.

3.2 Hardness test

This test is performed by using hardness (Shore D) and according to (ASTM D-2240) standard at room temperature. Samples have been cut into a disk with (40mm) and a thickness of (5mm) as shown in **Fig.4** while **fig.5** shows hardness device used in this research. For each specimen three hardness measurements were taken and the average hardness is calculated.

3.3 Thermal conductivity test

The Lee's disc, manufactured by Griffin and George, Ltd., is used to measure thermal conductivity. The apparatus shown in **Fig.6** consists of four identical copper discs of (40mm) in diameter and (12.25 mm) thickness, one of them includes an electric heater inside denoted by (H). The specimen (S) with the (40 mm) in diameter and (5 mm) thickness as shown in **Fig.7** is placed between the discs (A) and (B), while the heater (H) is sandwiched between (B) and (C) discs. Temperatures of (A), (B) and (C) discs are measured by using three thermometers. Thermal conductivity coefficient is then calculated according to eq.(3) & (4). The average of three measurements is taken for each specimen to minimize the possible errors.

$$IV = \pi r^2 e(T_A + T_C) + 2\pi re\left(d_A T_A + \frac{d_S}{2}(T_A + T_B) + d_B T_B + d_C T_C\right) \quad \text{……………….. (3)}$$

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

3.4 Water absorption

Disc specimens were prepared with diameter of 40 mm and thickness 5mm in order to obtain the water absorption of the composite material. The specimens weighted before and after immersion in water according to ASTM D 570 standard as shown in **Fig.8**. The increase in the weight of the specimens was calculated by using equation (5):

$$\text{Water absorption} = \frac{\text{final weight} - \text{original weight}}{\text{original weight}} \quad \text{……………………………….... (5)}$$

The specimens were immersion for one hundred days in water and it was weighted every ten days.

4. Results and Discussion

4.1 Wear Test

Wear tests were carried out for all specimen prepared from polyester resin and polyester with different weight fractions of reinforcement particles. Pin on disc wear test carried out for all the specimens different diagrams are sketched and presenting in **Fig.9** and **Fig.10.**For different percentage of weight fractions under various test conditions.(Weight fraction, and applied Load).

4.1.1 The effect of weight fraction:

The samples presented a good wear resistance with the increasing in weight fraction of (MgO, CaCO3, and SiO2) particles as shown in **Fig.9.** When we compered the wear resistance results of composite material after adding the reinforced particles with the result of polyester specimen we can observed an increasing about (62.5%, 42%, and 36.75%) in wear resistance respectively.

4.1.2 The effect of applied load:

The effect of various normal applied loads on the wear rate was studied for specimens before and after adding the reinforced particles with constant test conditions such as sliding time (900 sec), sliding distance (1507.2m) and the rotating disc speed 200 rpm. From the results we can observed the all the specimens have a decrease in wear resistance with the increasing in normal applied load. This behaviour can be discussed simply when a high load applied to the specimen surface more fraction will happened on it and thus leads to increasing wear rate.

The increase in wear rate of composite materials with 15% (MgO, CaCO3, and SiO2) shown in **Fig.10**. The increase recorded appeared by (34.4%, 47.5%, and 62.6%) respectively in wear rate with load increasing, but when compared with polyester specimen at the same test conditions its observed increase in wear resistance recorded by (54.2%, 35,3%, and 22%) respectively.

4.2 Hardness test

Hardness test type shore (D) has been carried out on polyester before and after adding the reinforcement particles and the average of three readings in each case taken to obtain higher accuracy results.

From **Fig.11** it can observed that the addition of reinforcement materials leads to increase the hardness of the composite material and the specimens reinforced with 15% MgO have higher hardness than $CaCO_3$ and SiO_2 specimens. A similar behavior seen by Aseel Mahmood et.al when used alumina particles as reinforcement material to polyester resin with (20µm) grain size and 8% weight fraction **[11].**

4.3 Thermal conductivity

The thermal conductivity of prepared composites specimens are measured by Lee's disc technique and the experimental results are shown in **Fig.12** .It can be see that the addition of ceramic fillers (MgO, $CaCO_3$, and SiO_2) to polyester resin leads to decrease the thermal conductivity will be high as there results good agreement with result obtained by **[9]**. And the use of MgO gives the best results as insulation material between the other materials uses in this research.

4.4 Water absorption

Water absorption behaviors of the composite in water immersion against the time in (days) are shown in **Fig.13, 14, &15**. The addition of (MgO, $CaCO_3$, and SiO_2) particles leads to increase the water absorption with the increasing in reinforcement material weight fraction%. A similar behavior was seen by N. W. A. Razak and A. Kalam with the addition of natural fiber or particles the water absorption increase due to the poor interfacial bonding made the composite material may be containing voids and porosity **[12]**.

5. CONCLUSIONS

1- The wear rate for all the prepared specimens was increased with the increasing in applied load.

2- The addition of reinforced particles leads to increase the wear resistance of composite material better than polyester specimen without reinforcement material.

3- The mixture of 15% MgO with polyester resin has the highest wear resistance, which is 62.5 % better than that polyester specimen.

4- MgO- Polyester composite has the best wear resistance, hardness, thermal in when compared with CaCO3-Polyester and SiO2-Polyester composites.

5- The addition of (MgO, CaCO3, and SiO2) particles to polyester resin leads to increase hardness and water absorption with the increasing in reinforcement material weight fraction.

6- The thermal conductivity decreasing with the increase in reinforcement weight fraction.

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Table (1): Physical and mechanical properties of polyester resin.

Flexural strength (MPa)	Specific heat (J/Kg.K)	Tensile Strength GPa	Density g/cm^3	Young's modulus GPa
45	1300	40	1.09	3

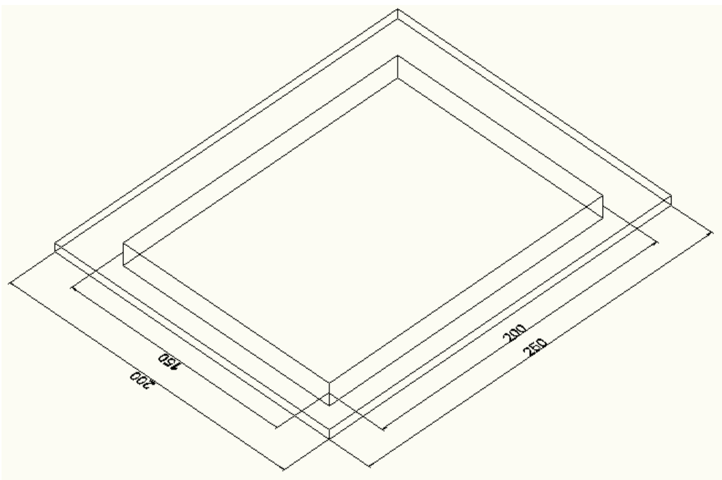

Fig. 1: The shape of the mould.

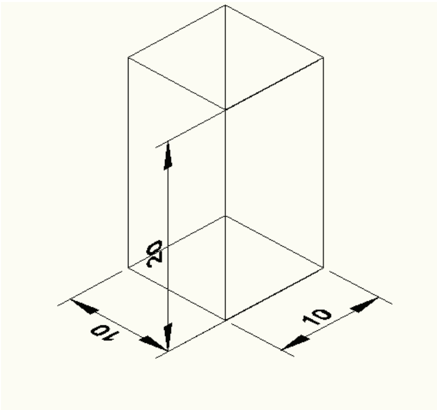

Fig (2): Standard wear test specimen.

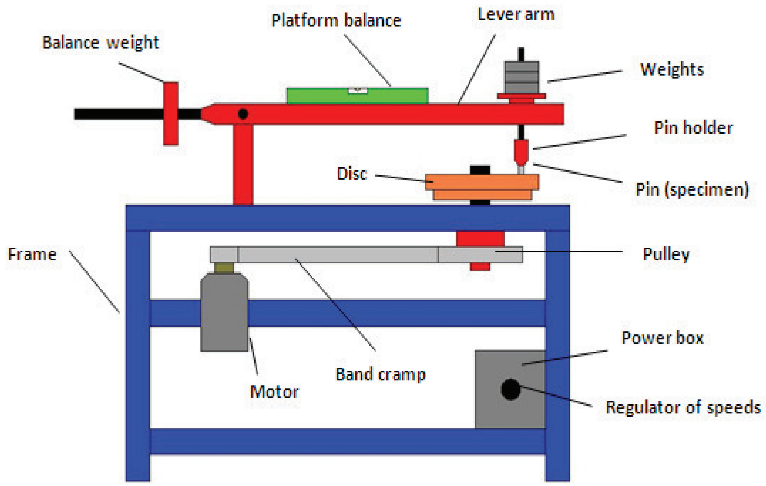

Fig.3: Schematic of pin-on-disc wear testing machine.

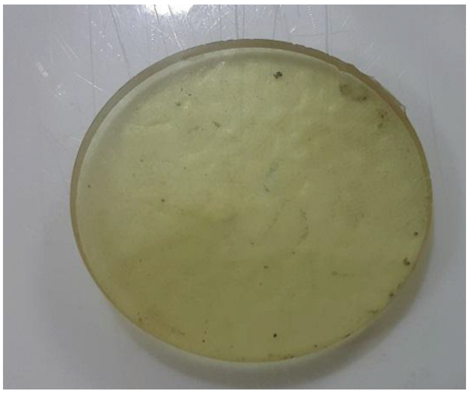

Fig.4: Hardness test device

Fig.5: Hardness test specimen.

Fig.6: Thermal conductivity device

Fig.7: Thermal conductivity specimen

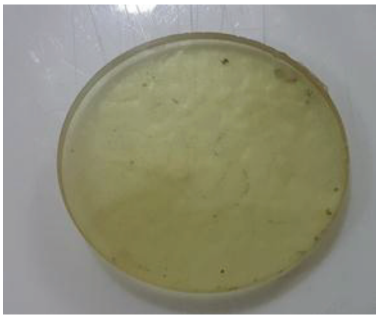

Fig.8: Water absorption specimen.

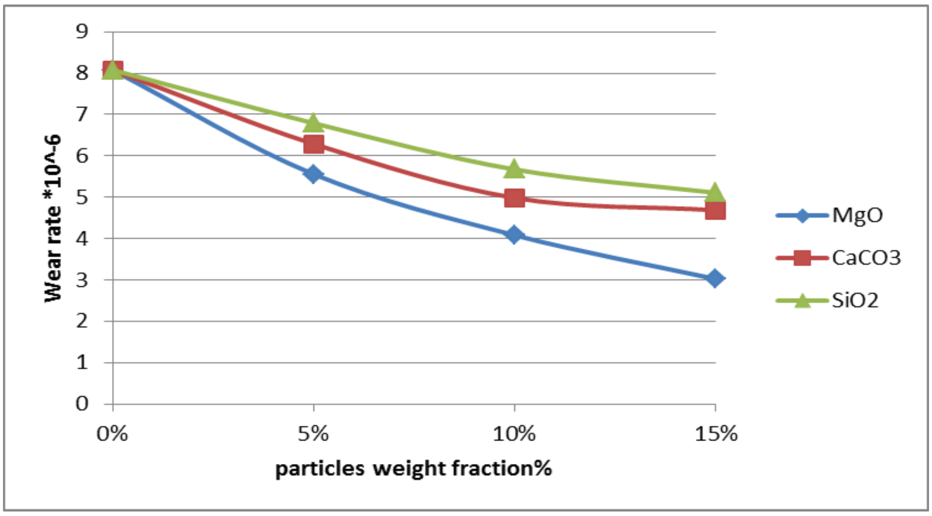

Fig.9: Effect of weight fraction on wear rate of MgO, $CaCO_3$ and SiO_2 composites.

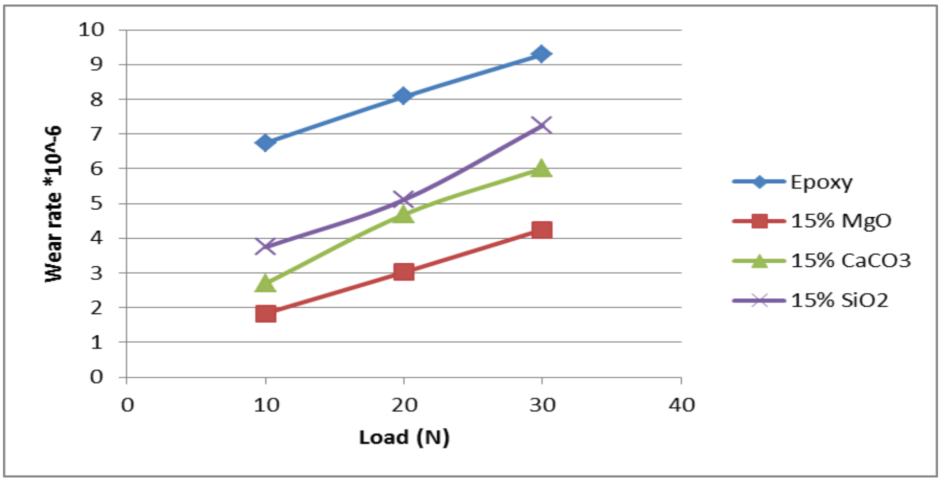

Fig.10: Effect of load on wear rate of MgO, $CaCO_3$ and SiO_2 composites.

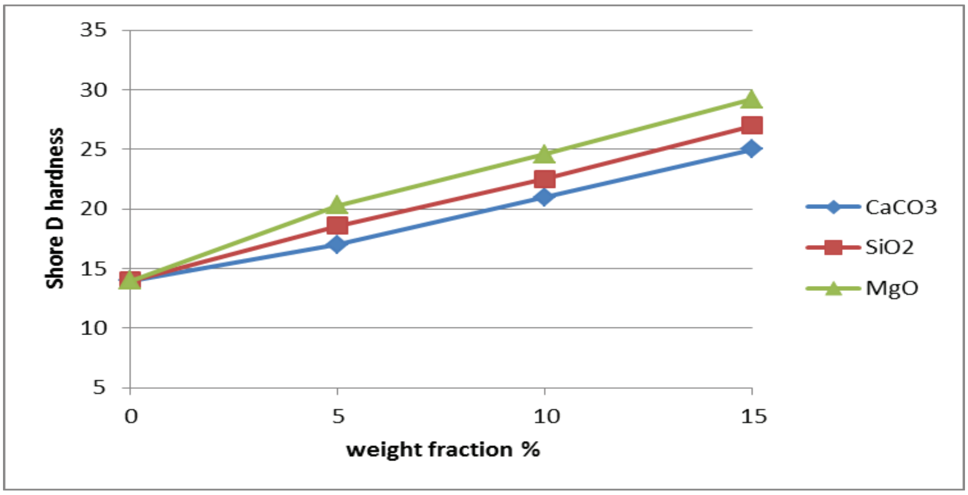

Fig.11: Effect of weight fraction on hardness of MgO, $CaCO_3$ and SiO_2 composites.

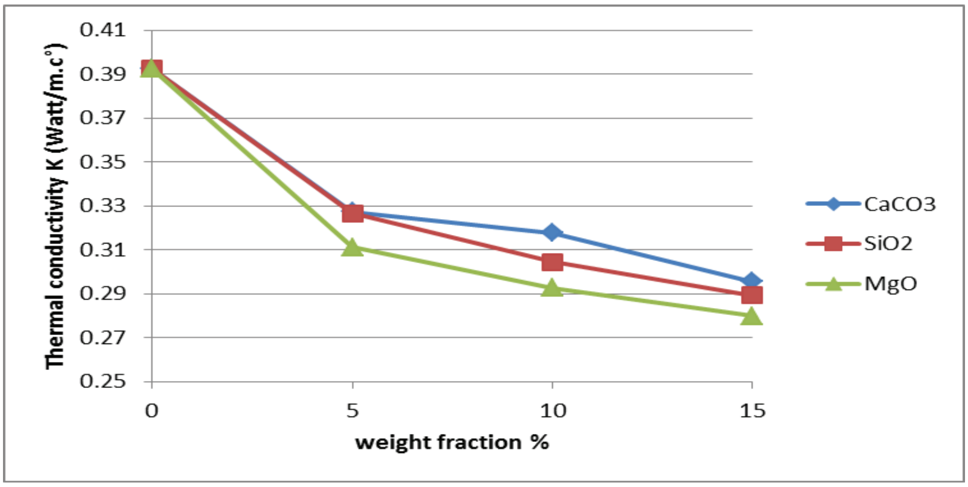

Fig.12: Effect of weight fraction on thermal conductivity of MgO, $CaCO_3$ and SiO_2 composites.

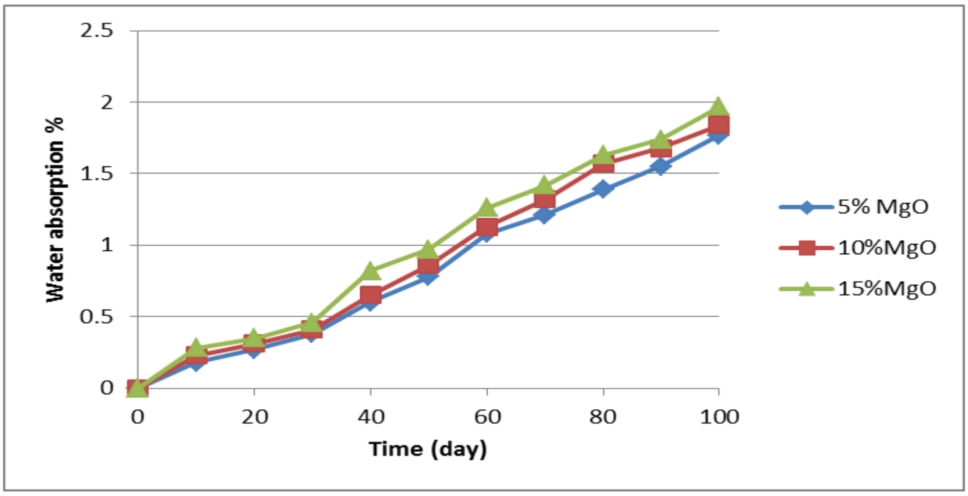

Fig.13: Effect of MgO particles on water absorption.

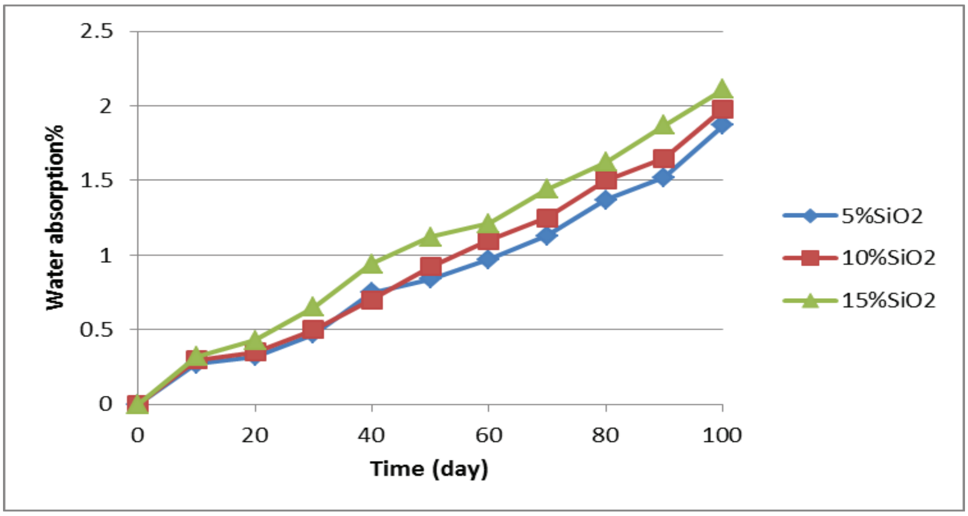

Fig.14: Effect of SiO_2 particles on water absorption.

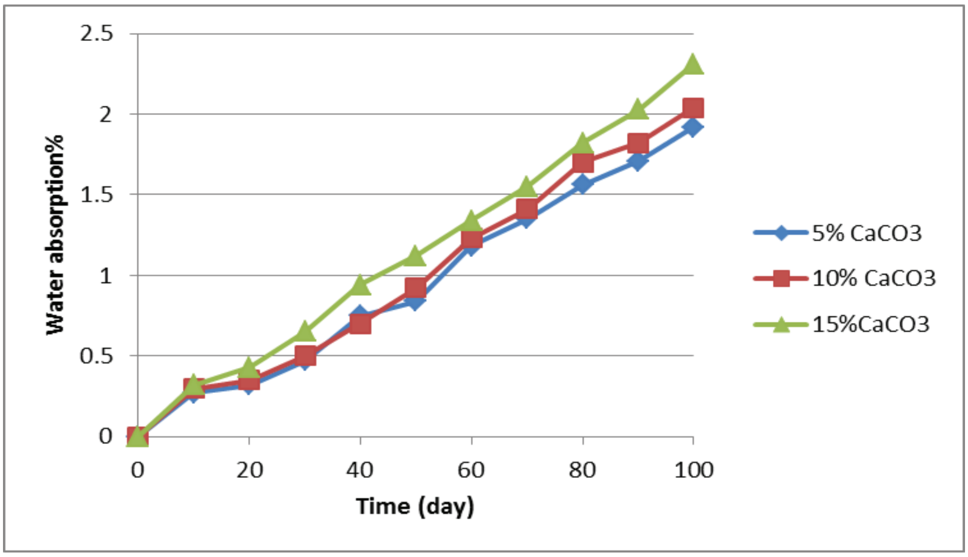

Fig.15: Effect of $CaCO_3$ particles on water absorption.