The Effect of Waste Ceramic Materials (Iraqi Stones Dust Powders) on The Mechanical Properties of Epoxy Resin

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Abstract

Using waste materials, which have a high pollution on the environment, as an improvement to the properties of a weaken material such epoxy resin become a good achievement. Iraqi stones dust powders have been used to improve the mechanical properties of epoxy resin. Impact strength and fracture toughness from impact test, Young`s modulus from tensile test, Shore hardness, fracture toughness and thermal conductivity have been investigated. The percentages of the ceramic powders have affected all the above properties and increased the values of them about twice. The highest values were at 12% and then decreased. Also the particle size of this powders has affected these properties, where the lowest particle size (25µm) has the best values.

Keywords : Stones dust, Impact strength, fracture toughness, Young`s modulus and thermal conductivity.

تأثير فضلات المواد السيراميكية (غبار الصخور العراقية) على الخواص الميكانيكية لراتنج الايبوكسي

الخلاصـــــة

أستخدام فضلات مواد لغرض تحسين خواص مواد اخرى مثل راتنج الايبوكسي يعتبر ذات جدوى. استخدمت غبار الصخور العراقية التي تستخدم بكثرة في واجهات البناء لغرض تحسين الخواص الميكانيكية للايبوكسي .

تمت دراسة متانة الصدمة ومتانة الكسر من أختبار الصدمة وكذلك معامل المرونة من اختبار أنحناء الشد وقياس الصلادة بالاضافة الى التوصيلية الحرارية .

لقد اثرت النسب المضافة من المسحوق السيراميكي على كل الخواص اعلاه حيث ازدادت هذه الخواص للضعف تقريباً وكانت نسبة 12% هي الاعلى قيمة ثم بدأت الخواص بالانخفاض كذلك كان للحجم الحبيبي تأثير كبير على هذه الخواص حيث أفضل خواص كانت للحجم الحبيبي (25 µm) .

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Introduction

It would difficult to imagine our modern world without polymers. They are an integral part of everyones life style with applications varying from common place domestic articles to sophisticated scientific and medical instruments, because they offer advantages such as lightness, resilience, resistance to corrosion, transparency ease of processing etc. One of the most popular of polymers materials is the epoxy resin which has been widely used as protection system of heterogeneous composites in many structures [1], because of its outstanding process ability, excellent thermal resistance, good electrical insulating properties, and strong adhesion, affinity to heterogeneous material with a higher mechanical properties under heavier loading .

They have a broad range of physical properties, mechanical capabilities and processing conditions that make them invaluable compared to other thermosetting resins,[2]. But their poor mechanical properties and low thermal conductivity are a major drawback. Therefore , solid filler ceramic powder or fibres have been incorporated to epoxy resins [3].

So polymer composites filled with ceramic powders are of interest for many field of engineering application. This interest arises from the fact that the dielectric properties of such composites are close to the properties of ceramic materials, where as the mechanical properties and processing methods are typical for plastics [4].

So composite materials can provide superior and unique mechanical and physical properties because it combines the most desired properties of this constituents which suppressing their least desirable preperties .

Generally epoxy is brittle, but to meet various applications needs; toughened epoxies have been developed that combine the excellent thermal and mechanical properties [5]

Kareem [6] have studied the mechanical properties of nickel particles reinforced epoxy resin using nickel powder with different particle sizes and volume fraction and he found that modulus of elasticity and yield stress values have been raised with the increasing of volume fraction of the powder

Al ubaidy [7] have studied the epoxy reinforced with fibres glass (30% volume fraction) and Kevlar fibres. Most of the mechanical properties (tensile , impact , flexuaral strength) are increased with volume fraction but hardness and compressive strength are decreased.

Hussien [8] studied the physical and mechanical properties of epoxy reinforced by palm fibres at different volume fraction. The fibres enhanced the dielectric properties of the composite and also improved the physical and mechanical preperties .

Al Khazragi [9] studied the mechanical, thermal and electrical properties of epoxy resin reinforced with different clays. All the physical properties of the composite were improved.

Al-Hassani and Areef [10] studied the effect of different chemical solution on the tensile strength of polymer composite. They showd that the tensile strength of the composite improved with these chemical solution.

Abdul Noor et al [11] have presented a theoretical aspect of some mechanical properties of epoxy resine reinforced by nickel particles , carbon black and borosilicate glass at 45 wt. % , They used two models first is the rule of mixture and the second of the theory of elasticity .

Marur et al [12] have studied the effect of particle size and volume fracture of sperical alumina particles on the fracture toughness of epoxy resin. They found the when the particle size is 5µm the fracture toughness of the composite increased with increasing volume fracture.

They found that the aluminium filler contents did not affect the moisture diffusivity in the epoxy adhesive significantly but the effect of salt concentraction was significant; the higher the salt content in the test solution, the higher the moisture diffusivity in the adhesive.

Zhou and YU [13] were prepared microsized aluminium / epoxy resin composites, and the thermal and dielectric properties were investigated it terms of composition, aluminium particle sizes, frequency and temperature. They found that 48% volume fraction of aluminium have a high thermal conductivity and a high dielectric permittivity, but a low loss factor, a low electric conductivity and a higher breakdown voltage .

Due to the huge construction in the country a million tonages of stones used for this purpose which need some machining. This machining remains huge of dust in differnt particle sizes, which has polluted the environment.

The aim of this study is using a waste material such Iraqi stones dust to improve the mechanical properties of epoxy resin .

2- Experimental work

Hand lay-up method is used to prepare the composite samples . Moulds are used from pyrex material in different dimensions for different properties which studied .

Epoxy resin (Euxit 50 KI) is mixed with hardener (Euxit 50 KII) in ratio of (3:1).

The ceramic powders (IRAQI stones dust) were milled and sieved at three particle sizes group (-25µm , -53 µm and –75µm) by using a ball mill and sieving method technique (- means less than).

Different volume fractions of ceramic powder (3 , 6 , 9 , 12 and 15%) for each particle size were mixed thourogly with the resin and the mixture is pourd into the moulds slowly in order to avoid air trapping .

All the samples were left to solidify at room temperature for 24 hours

2-1 . Characterization

2.1.1 Thermal conductivity

The test is carried out in accordance with Lee`s disk which manufactured by (Griffen and George Company, England)

The thermal conductivity (K) calculated from the below equation [14].

$IV = \Pi r^2 e(T_A+T_B) + 2 \Pi re (D_AT_A + \frac{1}{2} d_s (T_A+T_B) + d_BT_B + Tc]$ …....(1)

$K (T_B-T_A / ds) = e [T_A + 2/r (d_A + (1/4) ds) T_A + (1/2r) ds T_B]$………(2)

Where

I = current in Ampere .

V= applied voltage in volt .
r = radius of disk in (mm).
e = heat flow per unit area per second (w /cm^2 . C$^\circ$).
T_A, T_B, T_C = temperatures of the disks A,B,C (C$^\circ$).
d_A, d_B, d_C = thickness of the disc A,B,C (mm).
ds = thickness of the sample (mm).
K = thermal conductivity (watt / m .C$^\circ$).

2-1.2 Impact and fracture toughness test .

This test is performed according to (ISO-197) at room temperature .
The impact strength is calculated by applying the below relationship :

$$G_c = U_c / A \qquad \text{……….. (3)}$$

Where G_c is the impact strength (J/m^2), Uc is the fracture energy (joule) which is determined from charpy impact test instrument .
A : cross section area of the specimen fracture toughness can be calculated by using the relationship below [1]

$$Kc = \sqrt{G_c E} \qquad \text{………… (4)}$$

Where Kc is the fracture toughnes (MPa m$^{1/2}$)
G_c = impact strength (J/m^2)
E = modulus of elasticity (MPa) .

2-1.3. Hardness test

This test is performed by using shore hardness (D) which according to (ASTM D 2240) at room temperature

2-1.4 Elastic modulus test from stress- strain curves (tensile test).

Load – elongation curves have obtained for all the samples and the slope of these curve, the modulus of elasticity can be calculated.

3- Results & Discussion

Mechanical properties of polymers reinforced by ceramic particles are affected by many factors such bending strength, adhesion force between the matrix and ceramic powders and the adhesion between the layers.

Fig. (1) shows the X-ray diffraction of ceramic powders which has multi phases as indicated by cards of X-ray including clay (bentonite), Al_2O_3 , SiO_2 and clay . The sharp peak at 2θ = 31 belong to bentonite phase .

Figs (2-4) represent the relation between stress and strain for different percentages with different particle sizes (25,53 and 75 micron) .The basic target of this test is to show the load effects on the surface level of the specimen. The results are shown in the figures (2-4) . the reinforcement materials in polymeric composites usually bear the external strain because the polymeric matrix transmits the stress to the powders through the interface .It is clear that ceramic powders have affected the bending of the composite specially with the percent (12%) . Also the lower particle size has the highest effect for all the properties .

Fig. 5 shows the effect of ceramic content on modulus of elasticity at different particle sizes, Young`s modulus was increased as the percentage is increasing having the highest value at 12% and then decreased for each particle size ,again the lower particle size (25 µm) has the highest value at the lower percentages. This may be due to the good adhesion force between the matrix and ceramic powders which reduce the slipping between the layers , besides that ceramic particle has high Young`s modulus and the good distribution of ceramic powders in the matrix is another factor to increased the Young`s modulus .

Fig. (6) shows the effect of ceramic content on the impact strength of epoxy resin for different particle sizes . An increase in impact strength has been noticed for all the specimens compared to epoxy resine alone, where ceramic powders formed obstacle regions to the fracture to grow and which led them to the increase in the fracture due to the good distribution which resulted in the increase of toughness of the material again the same behaviour was appeared , The highest value of the impact strength was for 12% ceramic powder at 25 µm particle size , because the ceramic particles behave as a damper for cracks growth which increased the strength of the composite material besides the lower particle size which has more affecting on the impact strength (1) .

Fig .(7) shows the change in hardness values due to the effect of ceramic powders content and also the particle sizes of these powders. As it is known that hardness is a property which explains the state of the surface of the material. The tiny points made due to this test, make a ductile deformation happens first which leads to from a sign of the inserting tool on the surface of the specimen in most of hardness test .

So ductile material absorbs more quantity of energy .The results obtained in the above figure shows again 12% of ceramic powders has the highest value at the lower particle size.

Fig (8) represent the effect of different percentage of ceramic powder at different particle size on the thermal conductivity of the composite in polymeric materials ,where the thermal conductivity depends on molecular orientation and the crystalline volume . Also The thermal conductivity of a composites depends on many parameters including resin type , percentages of addition ,type of additive ,the distribution of powders and void percentages. The parameters of major influence on thermal conductivity are percentages of additions and conductivity percentages of both resin and powders [16] .

Fig (9) shows the effect of ceramic powders at different particle sizes on the fracture toughness Kc, 12% of ceramic powders has the highest value for all the particle size but it is the highest for 25µm particle size .

4- Conclusions

1- Using a materials waste (i.e Iraqi stones dust) enhancing the mechanical properties of epoxy resin and reduce the pollution.
2- Thermal conductivity of the composite increased twice as epoxy resin alone .
3- Mechanical properties such Young`s modulus , impact strength and shore hardness and fracture toughness increased also twice .
4- The lower particle size (- 25µm) has the highest values for the properties .
5- The ratio 12 wt% of ceramic powder has the highest value for impact strength and hardness and toughness.

5- References

[1] R.B Seymour " Modern plastic technology" Resten publishing co . lnc 1995 .

[2] Pascault H.P. Sauterean H. Ierda J. and Williams R.J . " Thermosetting polymers" Marcel Dekker, New York 2002 .

[3] Wei, Cui, Feipeng Du , J.Zhao , Y Yong , X-Xie and Yiu-Wing Mai " Improving thermal conductivity which retaining high electrical resistivity of epoxy composites by incorporating silica-coated multe-watted carbon nanotubes . Carbon Journal , Vol. 49, 2011, PP 495-500 .

[4] [W. Zhou and D . Yu " Thermal and dielectric properties of particle. Epoxy resin composites " J. of applied polymer Science" Vol. 118 , No. 6, 2010 ,PP 3156-3166 .

[5] S.K . Mazumdar" composite manufacturing " CPC press lnc. 2002.

[6] H.A. Kareem " study the influence of adding Nickel powder to thermosetting epoxy resin on the mechanical properties M.Sc thesis, University of technology , Baghdad ,IRAQ, 2002 .

[7] R.M.Alubaidiy " study the mechanical properties of multilayer of hyprids composites " M.S.C thesis. University of technology, Baghdad .IRAQ 2004 .

[8] H.J.Hussien " Studying some properties of Epoxy reinforced with natural and industrial materials " M.Sc thesis university of Technology . Baghdad .IRAQ 2005 .

[9] H.G. Al-Khazregi " M.Sc thesis university of Technology . Baghdad .IRAQ 2006 .

[10] E.S Al.Hassani and S.R.Areef " effect of different chemical solution on tensile strength of polymer composite Eng.of Tech. J. Vol. 28, No 4 , 2010,PP 768-772

[11] S.S.AbdulNoor, A.AL-Beriruti and M.H.Nashat " theoretical aspect of some mechanical properties of composites Eng.of Tech. Journal Vol 28 NO.6 2010 .

[12] P. R. Marur, R. C. Batra, G. Garcia and A. C.Loos. " Static of dynamic fracture toughness of epoxy / alumina composite with submicron lnclusions " Journal of materials Science, Vol.39. 2004 .

[13] W . Zhou, D.YU " Thermal and dielectric properties of the aluminium particle epoxy resin composite " journal of applied polymer science Vol. 118 , NO.6 2010 PP 3156 – 3166 .

[14]Y.E.P. Mamunya , V.V. Davydenko , P.Pissi and E.V.lebedev " Electrical and thermal conductivity of polymers filled with metal powders ; European Journal Vol 38, 2002 , PP 1887-1897.

[15] A Ban. " development and characterization of ternary thermosetting polymer blends, Ph.D thesis ,Department of applied sciences ,University of Technology 2006.

[16] A paliaik , M.A bdulla, A. Sampathy and B. Satapathy " A study on a possible concelation between thermal conductivity and wear resistance of particulate filled polymer composites "Materials and design .Vol 3, 2010 , PP 837-849 .

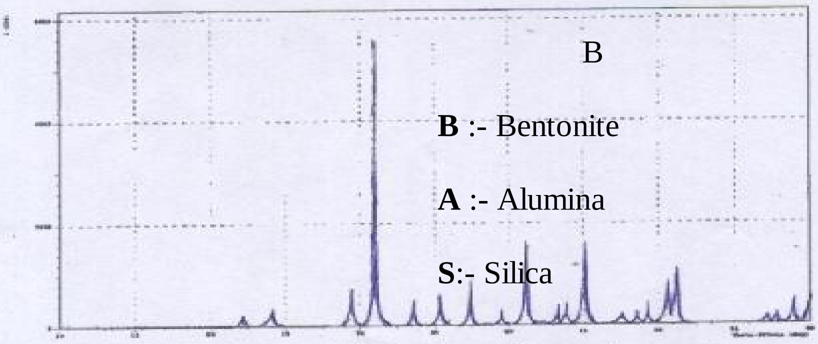

Fig.(1): X – ray diffraction of ceramic powder.

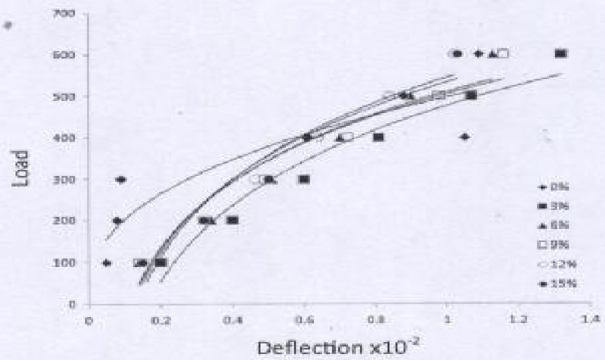

Fig.(2): Load – deflection relation for 75 μm ceramic particl size.

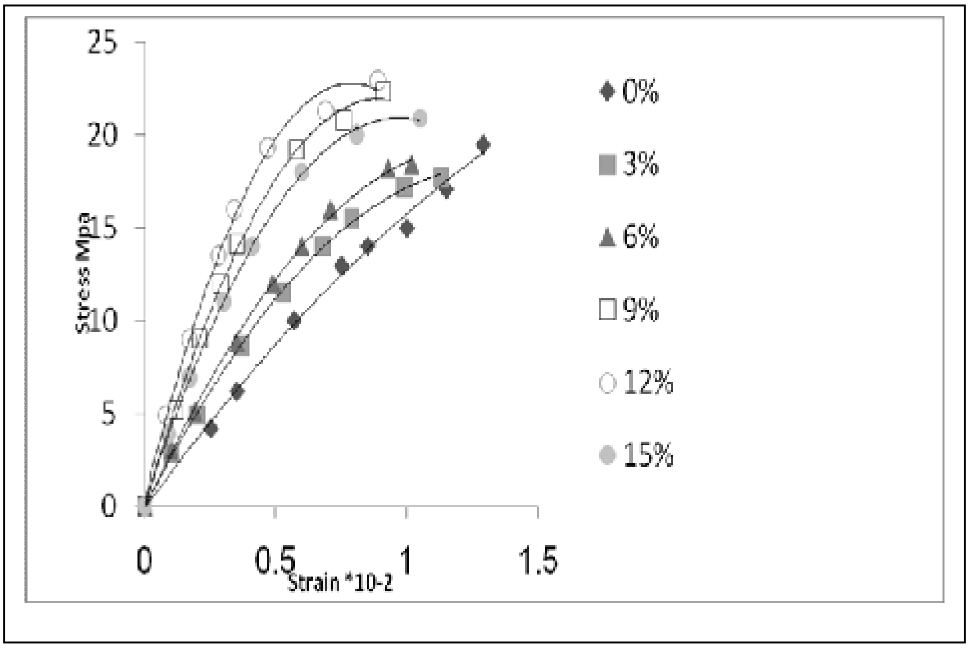

Figure (3): Stress-Strain curve for 53 μm ceramic particle size

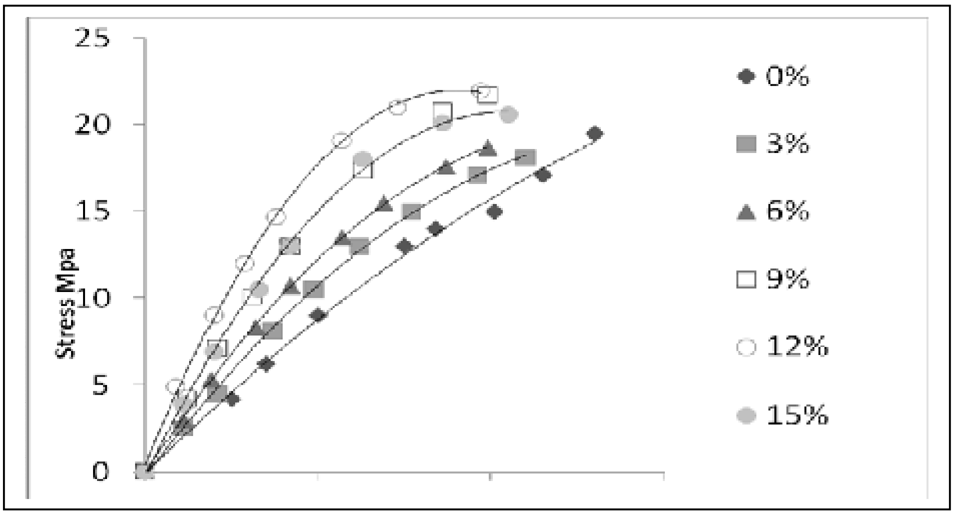

Figure (4): Stress-Strain curve for 25μm ceramic particle size

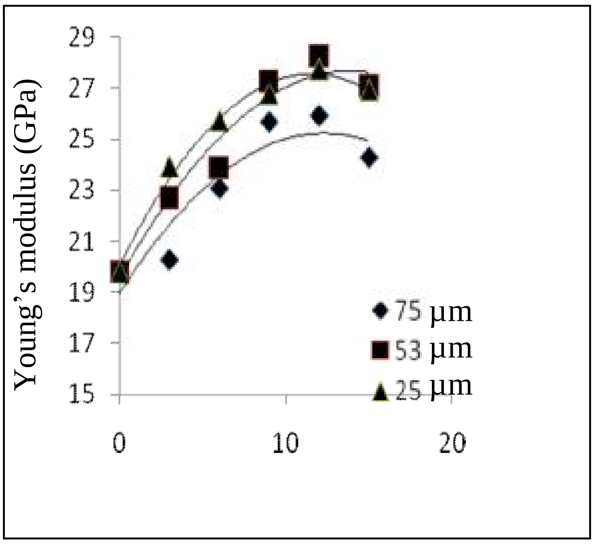

Figure (5): The effect of ceramic powders on the Young's modulus of composite.

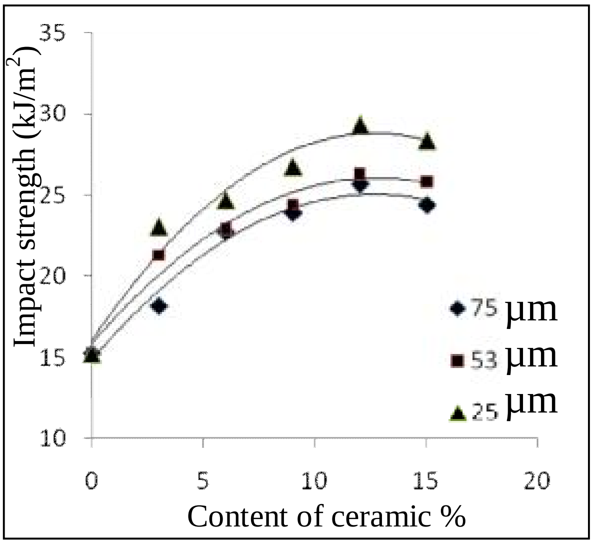

Figure (6): The effect of ceramic content on the impact strength of epoxy resin.

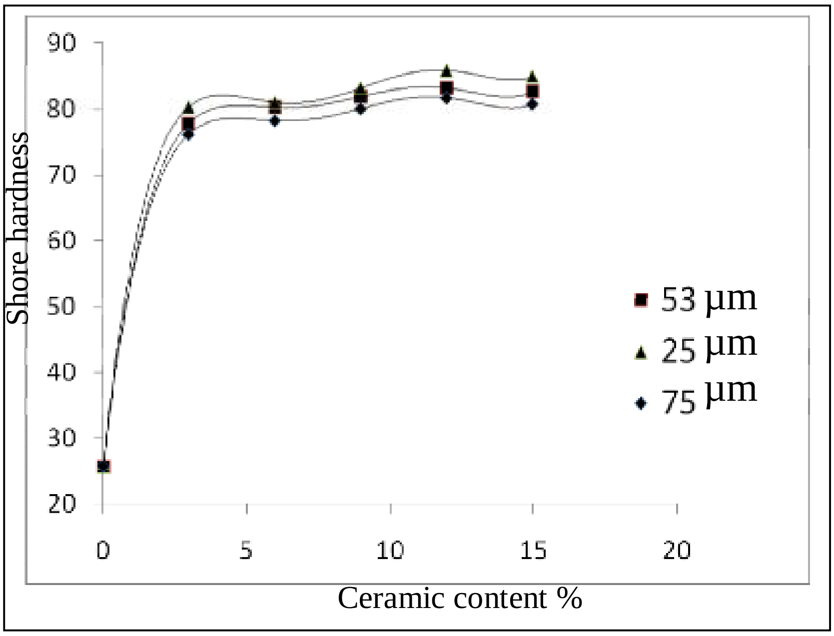

Figure (7): The relation between hardness and the ceramic content.

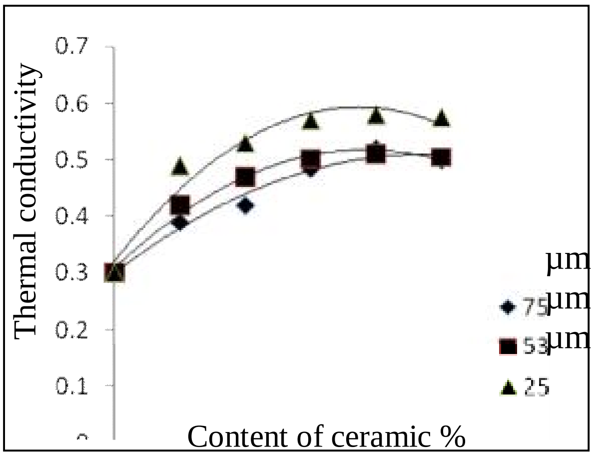

Figure (8): The effect of ceramic powder on the thermal conductivity.

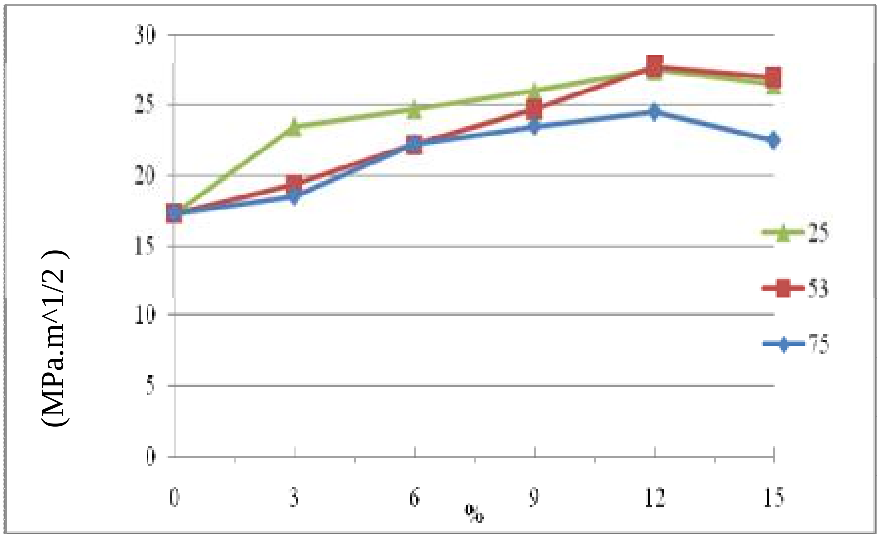

Figure (9): The effect of ceramic powders with different particle sizes on the fracture toughness of the composite.