Effect of Glass Powder on Some Mechanical Properties of Polymer Matrix Composite Material

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Abstract

This research deals with the study of the effect of adding glass powder of grain size (35μm) with different volume fraction (10%, 20%) to the blend of unsaturated polyester and polyurethane using hand lay-up method, after preparing the matrix from weight fraction (90%) of Unsaturated polyester and (10%) of polyurethane. The results have shown that the addition of particles to the polymer blends lead a great extent in mechanical properties, since testing bending, Shore D hardness and impact strength. It has shown that the values of young modulus, impact strength and hardness were increased with increasing of volume fraction of glass powder. Fracture surface of the samples were examined by using optical microscope with magnification (40 X) and the results showed that the nature of fracture is seems brittle fracture for all samples.

Keywords**:** Polyurethane, unsaturated polyester, glass powder, impact, bending, shore D hardness.

Introduction

Composites involving particles in a matrix are low cost and widely used. They are used in all plastics, natural and synthetic rubber, and in coating [١]. Fillers used randomly in rubbers then phenolic resin was used recently with wood flour and cellulose to improve physical properties due to aspect ratio. Ideal fillers own physical properties including [2].

Fillers are solid additives that are incorporated into plastic matrix to reduce cost of the compound, while reinforcing fillers are added to improve certain mechanical properties such as (modulus or tensile strength) depend strongly on size, shape and distribution of filler particles in the matrix polymer and a good adhesion at the interface surface [3].

Although termed inert, inert fillers can nonetheless affect other properties of the compound beside cost. In particular, they may increase the density of the compound, reduce the shrinkage and increase the hardness. Reinforcing fillers typically will increase the tensile, compressive, and shear strength, reduce shrinkage, increase the modulus, and improve the creep behavior [3]. For effective reinforcement, the particles should be small, evenly distributed throughout the polymer matrix, and must form a strong adhesive bond with the matrix [4].

Metal and ceramic fillers were used as a reinforcement to enhance the electrical and thermal properties of the composite in addition to improve the mechanical properties which are generally isotropic; that is, they are invariant with direction provided there is a good dispersion of the filler[1] [5].

Ceramic particles are hard but brittle and lack toughness. Glass spheres are widely used with polymers to give a composite which is stronger and stiffer than the polymer alone [3]. Silica (SiO_2) was used with thermoplastic polymers to reduce the thermal conductivity and thermal expansion of polymers, mechanism of reinforcing with powders give a high viscosity and good adhesion, depending on grain size of particles [5] [6].

Literature is replete [7] with the use of wood fiber, glass, rice husk, rice straw, etc, in the filling and reinforcement of various polymer matrices, thus yielding composites with better dimensional stability, improved mechanical properties, better thermal response among others. What the authors have not known from available literature is the use of groundnut husk powder as filler in any polymer matrix composite formulation. In this work therefore, it was intended to develop a composite material with polyurethane as the matrix and groundnut husk powder as the filler. The work also investigated the basic

mechanical properties (pertinent to shoe soles manufacture) of the developed composite.

Amar P. et al have a comparative study of different ceramic filler as (ash, alumina, SiC) in a glass-polyester composite system to improve its characteristic properties in addition of a mechanical one where the comparative analysis shows that with the incorporation of these fillers, the tensile strength of the composites decrease significantly. The flexural properties, inter laminar shear strength, density and hardness are also affected by the type and content of filler particles. It is found that the presence of SiC improves the hardness of the glass-polyester composites, whereas the other two fillers show marginal effect. The study reveals that the reduction in tensile strength is the minimum in case of fly ash among all the fillers [8].

Further, the composite with low fly ash content (10 wt %) exhibits improved flexural strength.

Other researchers used Kevlar fibers in a normal polymer composite in order to improve thermal and chemical resistance by applying with fumed silica filler [9][10].

The aim of this work

1- Improving the mechanical properties such as (hardness, bending and impact strength) for these composite systems.
2- Comparison which system has optimum properties.

Experiment Materials

1-Matrix Material

A- Polyester resin (UPE)

UPE is thermoset polymer with density (1.15 gm/cm^3) used as transparent liquid which transforms into a solid state after adding the hardener to it in a percentage of (100:2), according to the standard specification of manufacturing company at standard mixing time and temperature (15min, 30˚C) in order to achieve homogenous solution. In UPE low temperature curing is carried out. Curing is done with cobalt octate as accelerator and with either MEKP alone or with MEKP mixed with t – butyl perbenzoate.

B-Polyurethane (PU)

Polyurethane (PU) is any polymer composed of a chain of organic units joined by carbamate (urethane) links. Polyurethane polymers are formed through step-growth polymerization, by reacting a monomer (with at least two isocyanate functional groups) with another monomer (with at least two hydroxyl or alcohol groups) in the presence of a catalyst. It is used as liquid with density (1.0 gm/cm^3). Polyurethanes are applied to the manufacture of flexible, high-resilience foam seating; rigid foam insulation panels; microcellular foam seals and gaskets; durable elastomeric wheels and tires; automotive suspension bushings; electrical potting compounds; high performance adhesives; surface coatings and surface sealants; synthetic fibers (e.g. Spandex); carpet underlay; and hard-plastic parts (i.e. for electronic instruments) [11].

2-Reinforcing Materials

Glass Particles

Glass powder of grain size of (35 μm) and density (1.65 gm/cm^3) was used in this work. The composition of this material is stated in the Table (١):

Glass is not a single compound, but is a mixture of a number of metallic silicates. No definite formula can be assigned to glass and it has no definite melting point. Within certain limits, glass may be represented by the formula:

$X\ Na_2O$ (or $X\ K_2O$). $Y\ MO.\ 6\ SiO_2$

Where M is a divalent metal like Ca, Ba, Pb, Zn etc. X and Y are the number of molecules [12].

The basic ingredient of most glasses is sand, i.e. silica. Many of the mechanical properties of glasses are almost independent of their chemical composition. Glasses generally refer to hard, brittle, transparent material, have low ductility, low thermal expansivity and low thermal conductivity and thus have low resistance to thermal shock. They are resistant to many acids, solvents and other chemicals [13].

Table (١)
Chemical Composition for Glass Powder.

Components	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	Na_2O	K_2O
Weight%	52.55	0.18	0.75	0.56	1.50	9.10	7.20

3-Silica Foam

Silica foam, called (Aerosol), was used in this research. This material plays a great role in the control of viscosity. The main purpose behind using this material was to prevent precipitation both of silica and glass powder. A small portion of silica foam (1% of the total volume fraction) was added. The density of silica foam is (2 gm/cm^3) with grain size (0.12 µm).

Preparation Technique

Hand lay–up molding was used for preparing the samples under test with the following steps:-

Prepare polymer blend

UPE is mixed with its hardener gradually, and then UPE resin was added to polyurethane and blended gradually. The percentage of mixing was (90% UPE /10% PU) blend. After that, the mixture is layed-up in a mold prepared in advance and made of vulcanized iron with dimensions (25*25*0.5) cm^3.
The density of the blend was determined by using the relation [14]:

$$\rho_m = x_1 \rho_1 + x_2 \rho_2 \quad \text{.....(1)}$$

Where
ρ_m: the density of the matrix (polymer blend).
ρ_1, ρ_2 : the density of the first and the second polymer respectively (g/cm^3).
x_1, x_2: the percentages of the first and the second polymer respectively.

Prepare composite material

A binary blend (UPE/PU) reinforced with glass particles. At first, glass particles were weighed with silica foam such that they achieved together a volume fraction of (10%, 20%) Then, a blend was prepared as in the first mold; moreover, glass particles and silica foam were added gradually to the blend with continuous mixing by a spoon. Finally, the sample was layed-up in the mold prepared in advanced.

Volume fraction (V_p) is combined by the relations [15]:

$$M_C = M_P + M_m \quad \text{.....(2)}$$

$$V_P = \frac{M_P}{\rho_P} \quad \text{.....(3)}$$

$$V_m = \frac{M_m}{\rho_m} \quad \text{.....(4)}$$

$$\nu_P = \frac{V_P}{V_C} \quad \text{.....(5)}$$

$$\nu_m = \frac{V_m}{V_C} \quad \text{.....(6)}$$

$$\nu_C = \nu_P + \nu_m \quad \text{.....(7)}$$

Where :
M_m, M_P, M_C: mass of matrix, particle, composite respectively (g).
V_m, V_p, V_C: volume of (matrix, particle, composite) respectively (cm^3).

V_C = (length *width * thickness) of sample
ν_m, ν_p, ν_C: volume fraction of (matrix, particle, composite) respectively
ρ_m, ρ_p: the density of the matrix and particle respectively (g/cm^3) .

When the solidification process is finished, the mold was taken out of the mold. Then, the curing process is done in a temperature (60°C) for 2 hours. Finally, the sample was cut down into standard dimensions according to the standard qualities for fulfilling the specific tests in the work.

Mechanical tests

Impact test

The charpy impact test on unnotched specimens was determined using pendulum impact testing machine. It is made in New York, USA. The test is carried out in accordance with ISO-179 with dimensions of sample: length (55mm), width: (10 mm) and height: (5mm). It is made in New York, USA. Dimensions of specimens must be calculated from equation: (A = b*t) where A is the cross – sectional area of the specimen, b, t are the width and thickness of the specimen respectively. Hammers with (5 Jules) fracture energy are used.

Impact strength can be calculated from the following equation [14]:

$$I.S = \frac{\text{Fracture energy (KJ)}}{\text{Cross Sectional Area for the Sample } (m^2)} \quad \text{.....(8)}$$

Bending test

This test is named as (three points test made by Phywe Company–Germany). The bending tests were performed according to ASTM-D790 standard with dimensions of sample: length (100mm), width: (10 mm) and height: (5mm).The main purpose of this test is to find Young's modulus (E) (MPa) can be calculated from the equation [14]:-

$$E = \frac{MgL^3}{48IS} \quad \text{.....(9)}$$

Where is:

(*M/S*): slope calculated from curve [mass–deflection].

g : acceleration due to gravity, its value (9.81 m/ sec^2).

I : momentum of geometrical bending which could be calculated from the equation:

$$I = \frac{bd^3}{12} \quad \text{.....(10)}$$

b : width of specimen (m).

d : thickness of specimen (m).

L : distance between supports (m).

Hardness test

The hardness test is done with instrument called (Shore (D) Durometer) made by Italian company type (TH210). This test was preformed according to ISO 9001 standard. The hardness value will appear on screen of instrument and the reading depends on the degree of penetration.

Morphology study

The morphology of the particle and matrix surfaces was studied using optical microscopy model No. RMM7T with magnification (40X).

Results and Discussions

1. Impact test

Polyurethane acts as a plasticizer for the polyester thus the movement of the polymer chains increases resulting increasing the ability to absorb energy, which means increasing the fracture energy [١6].

Fig.(١) shows that the blend with (20%) volume fraction of glass powder is the highest value of impact strength comparing with other samples. This increasing may be related to decrease of voids, defect and a good adhesion (interface) between the matrix (UPE/PU) blend and the glass powder [17].

Fracture surfaces of samples are given in Figs.(2,3,4,5,6,7). The micrographs show that the crack surface is uniform along the crack path. Moreover, cracks propagate directly and there is no retardation in crack growth. This indicates the nature of fracture surface behaves as a brittle of the material, and there is no plasticity observed before final failure.

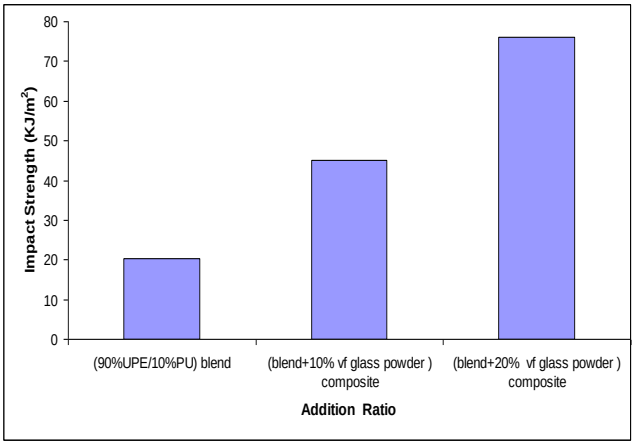

Fig. (1) Variation of Impact Strength values with addition ratio of glass powder.

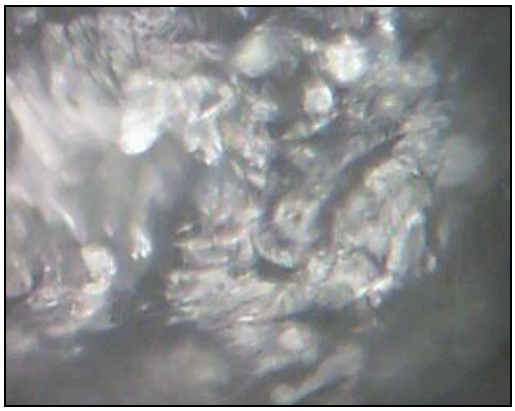

Fig. (2) Fracture surface from right side of (UPE/PU) blend.

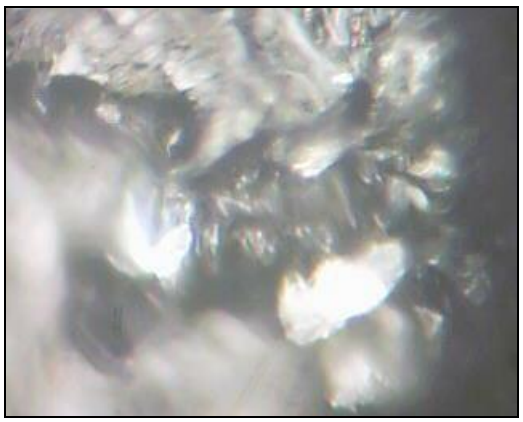

Fig. (3) Fracture surface from left side of (UPE/PU) blend.

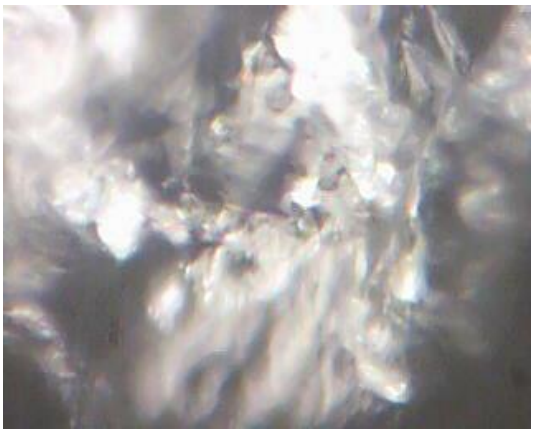

Fig. (4) Fracture surface from right side of (UPE/PU) blend +10% volume fraction of glass powder Composite.

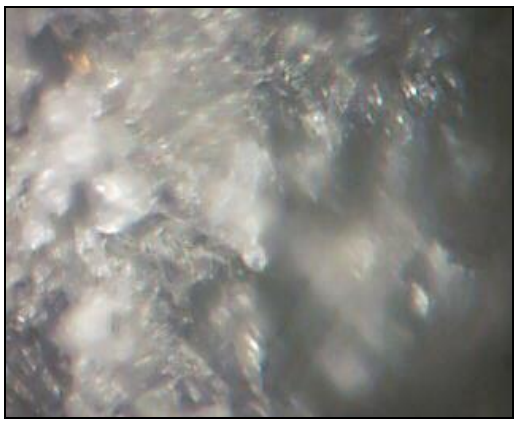

Fig. (5) Fracture surface from left side of (UPE/PU) blend +10% volume fraction of glass powder Composite.

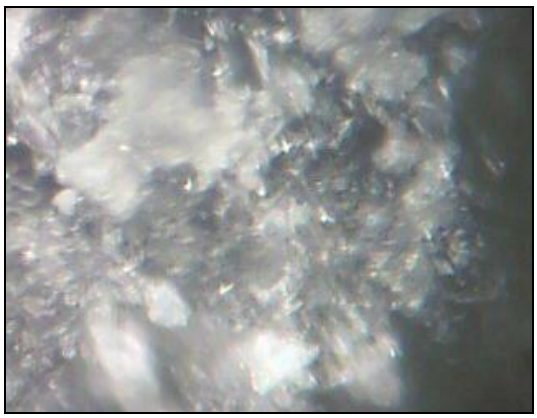

Fig. (6) Fracture surface from left side of (UPE/PU) blend +20% volume fraction of glass powder Composite.

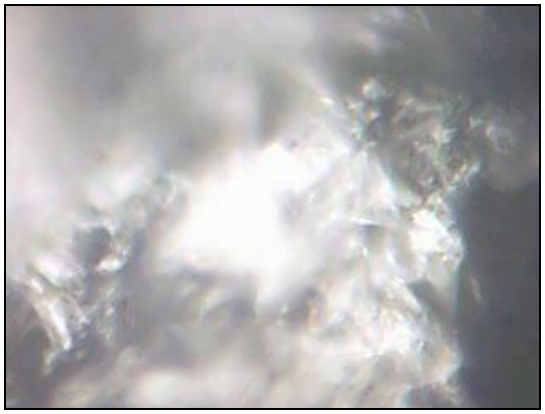

Fig. (7) Fracture surface from right side of (UPE/PU) blend +20% volume fraction of glass powder Composite.

2. Bending test

The relation between mass (Kg) and deflection (mm) was shown in Figs.(8,9,10). It was calculate that addition of glass powder with (10%, 20%) volume fraction to (UPE/PU) blend led to increase Young Modulus (E) value as in Fig.(11). The reason for the increase in modulus of elasticity of the composite material reinforced with glass powder may be related to the good adhesion between the particles and matrix material and good distribution of the powder in the matrix and also due to the presence of interactions between the matrix and the system processor (Cured System).

The particles of the reinforcement blend led to increase in modulus of elasticity and that arising from the possibility that the particles had become in contact with each other without the presence of the continuous layer of material, including the matrix material or to the ranks of particles surrounded by crust of matrix material [18][19].

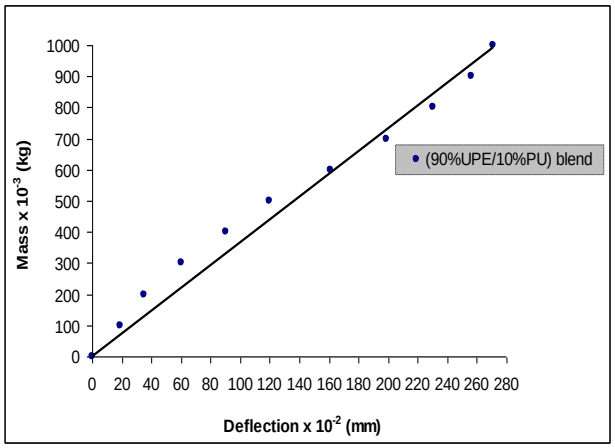

Fig. (8) Relation between Mass and Deflection of (90%UPE/10%PU) blend.

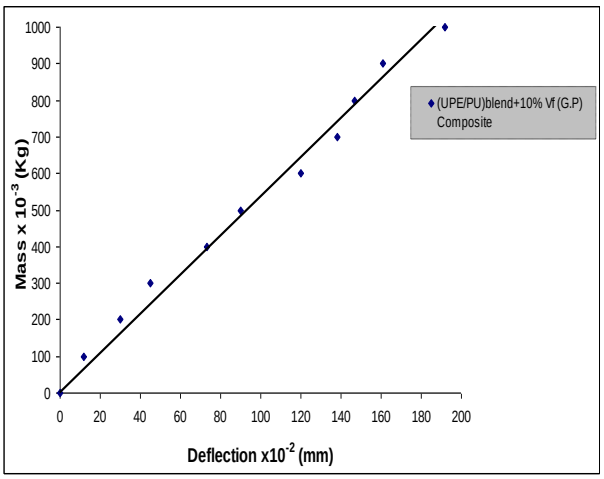

Fig. (9) The relation between Mass and Deflection of (UPE/PU) blend +10% volume fraction of glass powder Composite.

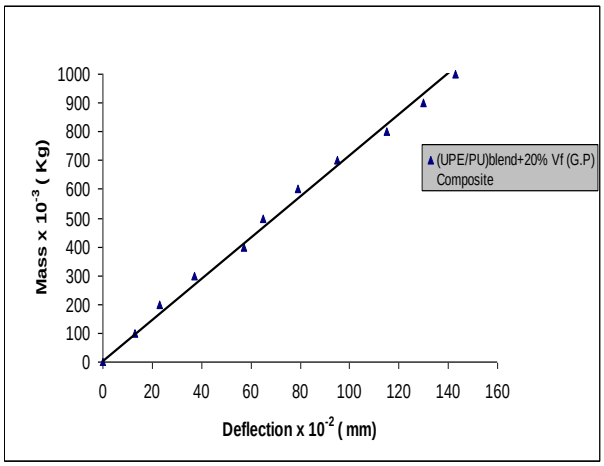

Fig. (10) The relation between Mass and Deflection of (UPE/PU) blend +20% volume fraction of glass powder Composite.

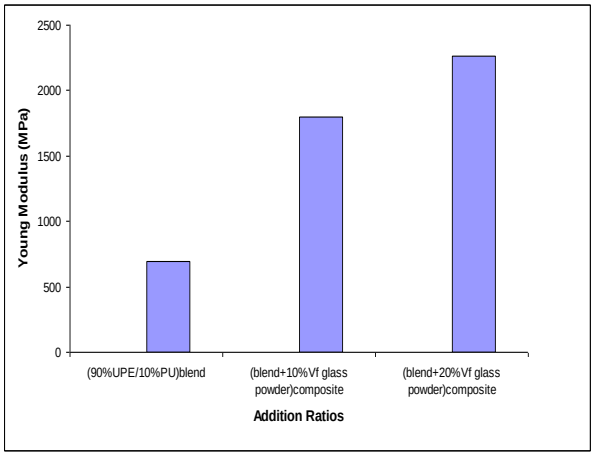

Fig. (11) Variation of Young Modulus values with addition ratio of glass powder.

3. Hardness test results

The hardness is a measure of resistance to indentation and, hence, will not be greatly influenced by the matrix [٢0].

From Fig.(١2) the results showed that the shore D hardness values increased for all sample after reinforcement with different volume fraction of glass powder explanation of that as follows:

For systems containing a mixture of inorganic component, the final products are usually hard and brittle. The incorporation of PU would be expected to impart flexibility to the inorganic glasses. On the other hand, the introduction of inorganic components can improve the hardness of the organic compounds [٢1].

Hardness values increased for all samples which strengthen by glass powder, and it was due to increased crosslinking and stacking (which reduces the movement of polymer molecules), which led to increased resistance to scratching material and cutting. Becoming more and more resistance to plastic deformation where the material hardness depends on the type of forces between atoms or molecules in the material the more the stronger linkage increases the value of hardness [٢2].

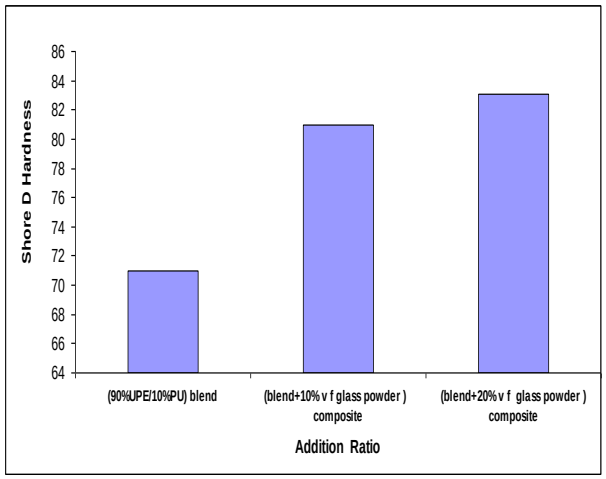

Fig. (12) Variation of Shore D Hardness values with addition ratio of glass powder.

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الخلاصة

تم في هذا البحث دراسة تأثير إضافة مسحوق الزجاج وبحجم حبيبي (μm 35) وبكسور حجمية مختلفة (10%, 20%) إلى خليط من راتنج البولي استر غير المشبع والبولي يوريثان والتي أنجزت بواسطة طريقة القولبة اليدوية بعد أن تم تحضير المادة الأساس و بنسبة وزنية (٩٠%) من البولي أستر الغير المشبع و (١٠%) من البولي يوريثان. أظهرت لنتائج إن إضافة الدقائق إلى الخليط البوليمري حسن وبشكل كبير الخواص الميكانيكية، حيث تم إجراء اختبار الانحناء وصلادة شور D و مقاومة الصدمة، وقد اظهرت النتائج ان قيم معامل المرونة ومقاومة الصدمة والصلادة لخليط من راتنج البولي استر الغير مشبع والبولي يوريثان يزداد مع زيادة الكسر الحجمي لمسحوق الزجاج. ان سطوح الكسر لجميع العينات تم فحصها بواسطه المجهر البصري وبتكبير (40 X) و لقد أظهرت النتائج ان طبيعة الكسر هو كسر هش لجميع العينات.