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Study the Mechanical Properties of Epoxy Matrix Composite Materials Using Glass Waste Particles

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Abstract

Recycling wastes is now of vital worldwide importance. The production of glass is one of several wastes, especially in the public, private, and construction sectors, due to the growing population, an increase in human activities. The goal of this work is to create a new product by solid waste (waste of glass) with modified properties, lowest cost and the possibility of employing them as substitute materials in a variety of applications. Four sets of samples were made by hand lay-up molding with 50% weight fraction, two sets of samples were made and cured at room temperature, while the others were cured at 50°C for two hours. Each set was made up of both reinforced and unreinforced epoxy. Composites reinforced with these particles showed increase in some mechanical properties when compared to elegant epoxy resin. The highest value of compressive strength was (80.86 MPa), Young`s modulus (2097MPa) and Vickers hardness (31.44) while Flexural Strength and Impact Strength were decreased. The best values were obtained for post cured at 50°C composite specimens. This proves that epoxy has been modified after being reinforced with waste glass, allowing it to be used in a variety of applications.

Keywords:Epoxy Matrix Composite ; Glass Waste ; Recycling ; Mechanical Properties; Particulate Composites.

Introduction

The main challenge in most materials engineers are development of durable composite material. In recent decades, particles ceramic filled with polymer composites have attracted the attention of scientists and scientific research, which revealed the good characteristics of polymer composite materials as a kind of engineering materials with improved corrosion and friction properties. Due to their good mechanical, tribological and thermal characteristics, polymer composites have become key part for industrial applications. In addition to their simple process ability and low cost. Polymer composites are engineering materials with unique properties. Epoxy is one of most common thermosetting resins applied in composites as a matrix [1-3].

In the late 1940s epoxy resins were commercialized, and since then they have been used in many industrial and commercial applications on a large scale. Epoxy resin has good chemical resistance, wear resistance, low shrinkage, better hardness, good adhesion and thermo mechanical properties, good dielectric strength, etc., epoxy under the influence of aggressive solvents can retain its physical and mechanical properties. Also epoxy resins bond to materials such as ceramics, metals, stone, wood, glass, and plastics[4,5].

Glass is a versatile and recyclable material[6] .With the rapid economic development of the country recently, the interest in the efficient use of waste glass has increased. Improving the economic and social benefits of the driving force is the main challenge of glass recycling. One of the main benefits of this technique. Simple operation, reduce the proportion of raw materials , Low price, high energy efficiency , environmental protection, show broad prospects for applications and great potential [7-9].

Tomáš et al. [10] Conducted on the possibility of demonstrating the appropriateness of using waste glass in polymer stabilization materials. A large amount of glass waste generated during the use, manufactured and recycling of various types of glass and its impact on the properties of the polymer, packaging glass materials have shown the best properties. Through the specification of tests for tensile properties, pull test, thermal resistance and

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temperature control during the polymerization process.

Yasmin et al. [11] graphite composites platelet reinforced, showed high improvement in tensile strength and modulus along from thermal stability compared with pure epoxy.

Anuja et al. [12-13] found that incorporation of CaSiO3 fine particles at 1-2% by weight with pure epoxy improves mechanical properties when compared to elegant epoxy resin. Also, the thermal behavior reinforced and unreinforced epoxy was studied by thermogravimetric analysis (TGA), to discover the thermal stability of the composites.

Agrawala et al. [14-15] analyzed the performance of epoxy-based composites filled with small-format solid glass pellets (SGM) , the densities of all manufactured samples were calculated. The results of mechanical and physical tests showed that the reinforced samples have less porosity, and improve flexural and impact strength , microhardness, though tensile strength is compromised marginally .With improved physical and mechanical wear and slip wear, currently manufactured composites can be used in applications where predominated wear.

Bharadwaja et al.[16] in this paper, the Epoxy Composite Association presented a study of the effect of the epoxy composites of SiO_2 particles on the epoxy composites gum. The results showed improvement in general mechanical and wear resistance such as Charpy's test, bending (three (3) points), impact test, mechanical properties and for use SiO_2 epoxy composites.

The plan of this study aims to recycle waste glass and utilizing as reinforcement for polymer matrix (epoxy resins) and manufacturing composite materials with new modified properties at the lowest cost for cleaning the environment from these solid pollutants and the possibility of using them as alternative material for different applications.

2- Materials and Methods

1. Waste glass

The source of waste glass used in this work was window waste featuring collected from local window glass vendors. After collection, separated forming bodies and cleaned by water to remove any impurities and glass powder were obtained after crushing window glass by an electric ceramic crusher and grind by a special ball mill made of porcelain. A sieving process was performed on the glass powder using a vibrator (sifting) / shaker, to gain particle size of (0.212-0.075 μ m). It's important to note that this process took two days.

2. Epoxy Resin

The epoxy resin used in the current work is Sikadur®-52 , purchased from Sika™, with a low viscosity inection-liquid ,high mechanical and adhesive strength. Epoxy is a two- part liquid system that consists of the resin and the hardener. When these two parts mix with ratio 2:1 they react upon time to form a solid cast after around 24 hours when left at room temperatures and post cured at 50°C for two hours . Epoxy was the matrix material of the composite prepared.

3.Preparation of Specimens

The manual method (Hand lay-up) was used to manufacture the samples required for the research using a ready-to-cast mold made of silicon as shown in figure (1), according to the American Society for testing and materials standard (ASTM). Pure and composite samples were prepared by mixing epoxy and glass particles by (50%) weight fraction and mixing them thouraly for (8-10) minutes to obtain a homoge dispersion. The mixture then was poured into the mold so that it flows regularly and continuously. Samples were demold after 24 hours from the time of casting at room temperature. Four groups of specimens were prepared, two of them were cured at room temperature and the others were cured for two hours at 50°C. Each group consist of reinforced and unreinforced epoxy.

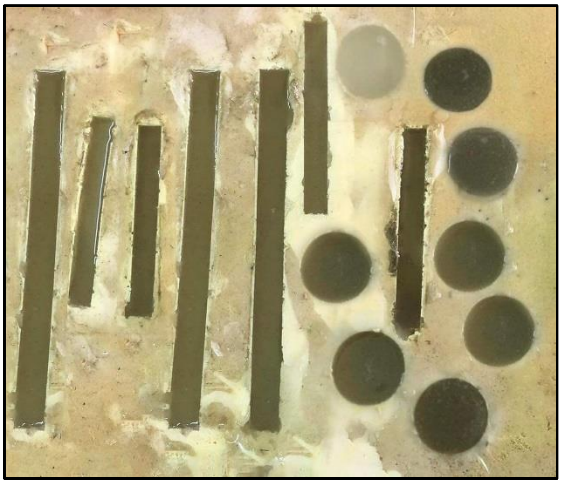

Fig.1. Mold.

Mechanical test

In each test, four sets of glass epoxy composites were used. The first set was cured at room temperature and the other post cured at 50°C for two hours according to (ASTM) and the same path was applied for each required test.

Bending Test

This test was carried out using the bending device (PHYWE)™, in compliance with the standards pacification (ASTM -790). Three-point bending test instrument was used to measure Young's modulus.

Vickers hardness Test

This test was caried out to determine the values of hardness for each sample. Microhardness instrument type LARYEE model HVS-1000, made in China. was used to determined the average value of hardness for all samples .

Compression test

This test was performed to calculate the compressive strength using a hydraulic press type (Leybold Harris No.36110) produced by British company .

Flexural Test

Jianqiao testing equipment™, manufactured in China was used. Flexural strength could be calculated using three point bending method.

Impact Test

It was used to execute the impact strength for the standard specimens without notch Charpy test machine, manufactured by Amityville Inc,™ was utilized.

3- Results and discussion

Bending Results

Figure (2-A) shows the relationship (mass-deflection) for each sample under test. From these results. It found that the composite material had a high bonding force between the matrix and the reinforced material, and this is due to the fact that the bending test is a slow stress that allows cracks to interact with the particles. The composite material led to reduce the deflection, and it was found that the modulus of elasticity of bending increases with the addition of glass powder. Figure(2-B) shows varies the values from (695.9) without glass powder to (2097) with silica for the samples at room temperature and from (700.5) without silica to (1257. 88) with silica for post-treatment samples. The critical point that affects the mechanical properties when manufacturing the particle-reinforced composite material is a good dispersion of particles within the resin [17,20].

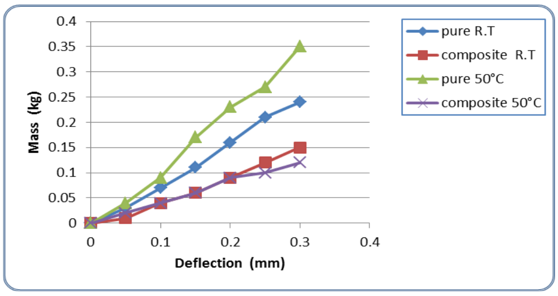

Fig. 2.A. (Mass – Deflection) curves for bending test of all samples.

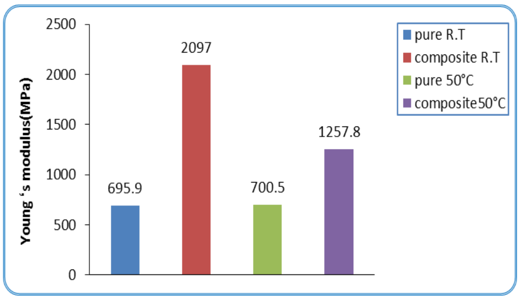

Fig.2.B. Results of Young's modulus of all samples

Hardness Results

The hardness property (Vickers hardness NO) of the samples were increased after adding glass powder to it, due to the increasing in the hardness of the materials surface , which increases the resistance of the materials for deformation under the applied force after incorporation of glass particles, which is characterized by high hardness, and that agree with Kadhim [1] and Agrawal [14]. It can be observed in Figure(3), the hardness increased from (16.03) without G.W to (31.44) with G.W for the epoxy at room temperature and from (18.8) without G.W to (26.87) with silica after the post curing.

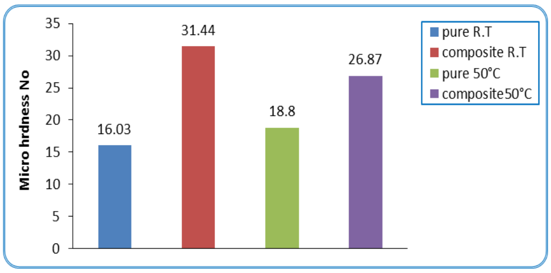

Fig.3. Results of Hardness number of all samples.

Compression Results

Compressive strength is the starting point, which is important in the process of searching for new or modified building materials which in turn leads to an increase in the resistance of the composite to the applied force due to the presence of glass particles, which is characterized with high compressive strength. It can be seen in Figure (4), the compressive strength increased from (75.87) without G.W to (77.25) with G.W for the composite at room temperature and from (75.49) without G.W to (80.859) with G.W for the heat treated samples .

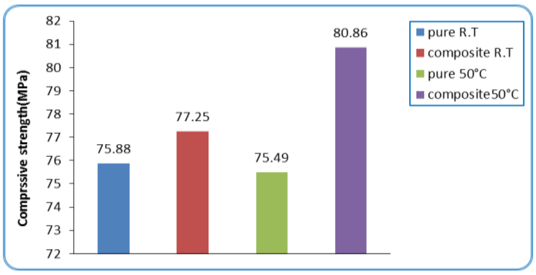

Fig.4. Results of Compressive strength of all samples.

Flexural Results

The addition of glass powder leads to decrease in the flexural strength of the particulate composites, which is agree with the [21]. It is shown in Figure (5), the flexural strength decreases from (60.66 MPa) without G.W to about (44.85MPa) with G.W for composite at room temperature and decreases from (48.15MPa) without G.W to (43.21 MPa) with G.W for the post cured samples.

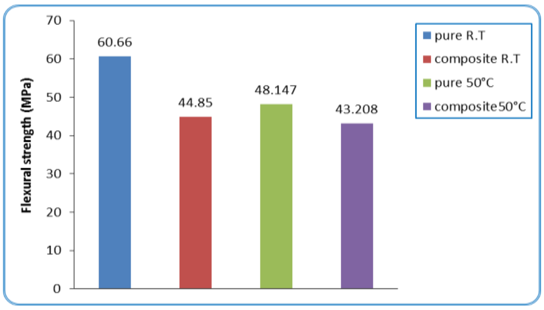

Fig.5. Results of flexural strength of all samples.

Impact results

In figure (6) the impact strength decreases from (8.91 MPa) without G.W to about (8.01MPa) with G.W for composite at room temperature and decreases from (15.17MPa) without G.W to (5.71 MPa) with G.W for the post curing .The addition of glass powder leads to decrease in the impact strength of the particulate composites, and that agree with Pravat [17] ,his means that increasing of G.W content causes the appearance of brittleness, which gives it strength ,make it a brittle material at the same time. Brittle material means material that allows crack propagation and is damaged by sudden breakage .These composites also exhibit typically poor resistance to lightning strikes and crack growth[17,19] and [22-25].

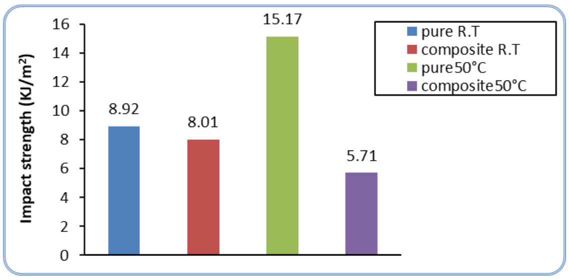

Fig.6. Results of impact strength of all samples.

Optical Microscope

Figure (7) shows the fracture surfaces results of samples under the optical microscope tested under the impact test for (a) pure epoxy at Room-temperature (b) waste glass-reinforced composite (c) heat-treated pure-polymer (d) waste-glass reinforced composite after being subjected to an impact load. It can be seen the good bonding nature at the interface between the matrix and the reinforcement there is no separation between the two phases within composite materials. This micro-structure gives a good idea of the adhesion between the epoxy resin and the reinforcement used in this work[26-28].

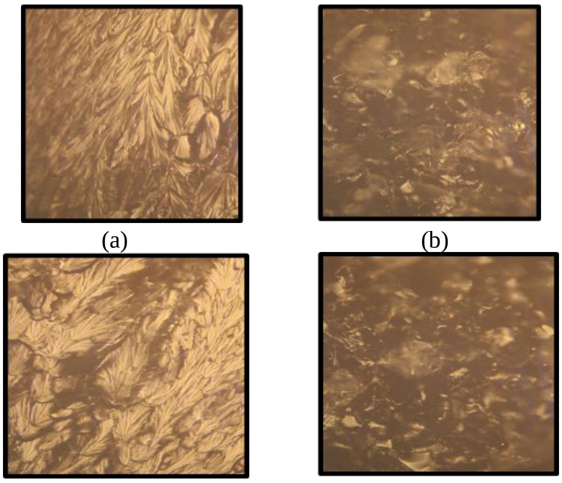

Fig.7. (a) Pure Epoxy at R.T, (b) Composite at R.T, (c) Pure Epoxy at 50°C (d) Composite at 50°C.

4. Conclusion

Glass waste could be invested to reinforce epoxy resin and manufacture improved composite materials.

Young s modulus, compressive and hardness increase with addition glass waste powder to Epoxy resin.

Impact and flexural strength decrease after the reinforcement with glass waste.

The microstructure of the prepared composite give us good idea about the bonding between the phases.

The current study promotes the recycling of glass waste and its use in the creation of composites with various sorts of improved qualities.

Conflicts of interest

The authors declared that there are no Conflicts of interest.

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Reference

[1] H. M. K. and L. M. H. Mohammed J. Kadhim and Departmentarukazu, “The wear characteristics of thermoset polymers composites filled with ceramic particles.” .

[2] H. S. Fadhil, “Flexural and Impact Properties of Epoxy Composites Reinforced with Peanut Shell Particles.” 2020.

[3] F. A. H. M. Engineering, I. hashembsb@yahoo. co. Department, University of Technology, Baghdad, I. M.S. Hamza Materials Engineering Department, University of Technology, Baghdad, I. R.R. Abdullah Materials Engineering Department, University of Technology, Baghdad, and R, "Effect of Silica Powder Addition on Mechanical Properties of Polymer Laminate Composite." 2017.

[4] Toohi, H. T. A. S., Rabeea, M. A., Abdullah, J. A., & Muslim, R. F. (2021). Synthesis and characterization activated carbon using a mix (asphalt-polypropylene waste) for novel azo dye (HNDA) adsorption. Carbon Letters, 31(5), 837-849.

[5] D. A. R. J. & K. K. A. Dr. Saad B. H. Farid*, "The Effect of Solvent Additions on the Mechanical Properties of Epoxy." 2010.

[6] B. P. Bohn, C. Von Mühlen, M. F. Pedrotti, and A. Zimmer, "A novel method to produce a ceramic paver recycling waste glass," *Clean. Eng. Technol.*, vol. 2, no. October 2020, 2021, doi: 10.1016/j.clet.2021.100043.

[7] C. Fu *et al.*, "Recycling of waste glass as raw materials for the preparation of self-cleaning, light-weight and high-strength porous ceramics," *J. Clean. Prod.*, vol. 317, Oct. 2021, doi: 10.1016/j.jclepro.2021.128395.

[8] D. F. A.Chyad, "The Effect of Waste Ceramic Materials (Iraqi Stones Dust Powders) on The Mechanical Properties of Epoxy Resin." 2011.

[9] M. Y. F. Esraa Q. Shehab a*, Zainab B. Mohammed b, "Estimation of the Components of Residential Solid Waste in Baqubah City and their Generation Rate." 2021.

[10] T. Žlebek, J. Hodul, and R. Drochytka, "Experimental Testing Suitability of the Waste Glass into the Polymer Anchor Materials Based on Epoxy Resin," *Procedia Eng.*, vol. 195, pp. 220–227, 2017, doi: 10.1016/j.proeng.2017.04.547.

[11] V. R and V. S. Rao, "Thermal, corrosion and wear analysis of copper based metal matrix composites reinforced with alumina and graphite," *Defence Technology*, vol. 14, no. 4. pp. 346–355, 2018, doi: 10.1016/j.dt.2018.05.003.

[12] A. H. Karle, M. R. Nukulwar, and V. B. Tungikar, "Evaluation of mechanical and thermal properties of epoxy composites reinforced with CaSiO3particulate fillers," *Mater. Today Proc.*, vol. 46, no. xxxx, pp. 325–330, 2021, doi: 10.1016/j.matpr.2020.08.188.

[13] Hamdoon, A., salih, W., Ahmed, S., Saleh, M. (2022). Modifying The Rheological Properties Of Asphalt Using Waste Additives and Air Blowing and Studying The Effect Of Time Aging On The Modified Samples. *Egyptian Journal of Chemistry*, 65(5), 447-453. doi: 10.21608/ejchem.2021.94414.4439

[14] A. Agrawal, S. Chandraker, and A. Sharma, "Physical, mechanical and sliding wear behavior of solid glass microsphere filled epoxy composites," *Mater. Today Proc.*, vol. 29, pp. 420–426, 2018, doi: 10.1016/j.matpr.2020.07.295.

[15] Hussein, A., Hamdoon, A., Ahmed, S., Mubarak, H., Saleh, M. (2022). Study of the effect of adding a blend of (ethylene vinyl acetate: styrene butadiene rubber) on the rheological properties of asphaltic materials. *Egyptian Journal of Chemistry*, (), -. doi: 10.21608/ejchem.2022.121325.5440

[16] K. Bharadwaja, S. S. Rao, and T. B. Rao, "Investigation of tensile and flexural behavior of epoxy and SiO2 composite: An experimental study," *Mater. Today Proc.*, vol. 45, pp. 2649–2652, 2021, doi: 10.1016/j.matpr.2020.11.514.

[17] Y. A. Ergün and Department, "Mechanical Properties of Epoxy Composite Materials Produced with Different Ceramic Powders." 2019.

[18] Saeed, Z., Saleh, M., sadeek, G. (2022). Synthesis and Biological Evolution of Novel Substituted 1,2,4-triazine from Sulfanilic Acid. *Egyptian Journal of Chemistry*, (), -. doi: 10.21608/ejchem.2022.132916.5870

[19] Saleh, A., Saleh, M., Chemistry, C. (2022). Synthesis of heterocyclic compounds by cyclization of Schiff bases prepared from capric acid hydrazide and study of biological activity. *Egyptian Journal of Chemistry*, (), -. doi: 10.21608/ejchem.2022.133946.5904

[20] A. Aladdin Ibrahim and M. Fleyah Hassan, "Study the Mechanical Properties of Epoxy Resin Reinforced With silica (quartz) and Alumina Particles *The Iraqi Journal For*," , *Mechanical And Material Engineering*, vol. 11 .no. 3. pp. 486–506, 2011.

[21] P. R. Pati, "Characterization of glass-epoxy composites using red brick dust particles," *Mater. Today Proc.*, vol. 18, pp. 3775–3779, 2019, doi: 10.1016/j.matpr.2019.07.315.

[22] H. Madhav, N. Singh, and G. Jaiswar, *Thermoset, bioactive, metal-polymer composites for medical applications*. Elsevier Inc., 2019.

[23] Aboraia, M., Elbadry, E., & Abdalla, G. (2020). Effect of Environmental Exposure on the notch sensitivity of GFRP Composites Used in Construction. *Egyptian Journal of Chemistry*, *63*(8), 2965-2975.

[24] Albozahid, M., & Mateab, S. (2022). Study the effect of adding mwcnts on the hardness, impact strength, and structural properties of composite materials based on epoxy polymer. *Egyptian Journal of Chemistry*, *65*(3), 1-2.

[25] Mohammedthalji, N., Ali, R., Saied, S. (2022). Thermodynamic & Kinetic Study of the Adsorption of Glycolic acid using a Natural Adsorbent. *Egyptian Journal of Chemistry*, 65(6), 505-520. doi: 10.21608/ejchem.2022.119362.5365

[26] Ali, R., Mohammedthalji, N., Al-Niemi, K. (2022). Study of Isothermal, Kinetic and Thermodynamic Parameters of Adsorption of Glycolic Acid by a Mixture of Adsorbent Substance with ab-Initio Calculations. *Egyptian Journal of Chemistry*, 65(6), 489-504. doi:10.21608/ejchem.2022.118101.5321

[27] Owaid, K. A., Hamdoon, A. A., Maty, R. R., Saleh, M. Y., & Abdelzaher, M. A. (2022). Waste Polymer and Lubricating Oil Used as Asphalt Rheological Modifiers. Materials, 15(11), 3744.

[28] Saied, S., Saleh, M., Hamdoon, A. (2022). Multicomponent Synthesis of Tetrahydrobenzo[a]xanthene and Tetrahydrobenzo[a]acridine Derivatives using Sulfonated Multi-Walled Carbon Nanotubes as Heterogeneous Nanocatalysts. *Iranian Journal of Catalysis*, 12(2), 189-205. doi: 10.30495/ijc.2022.1955651.1924