ISSN: 1813-162X (Print) ; 2312-7589 (Online)

Tikrit Journal of Engineering Sciences

available online at: http://www.tj-es.com

College of Engineering

TJES Tikrit Journal of Engineering Sciences

Enforcement of Epoxy with Silica Fume and Carbon Fiber

Amer Hameed Majeed *

Materials Engineering Department
College of Engineering
Al-Mustansiriyah University
Baghdad
Iraq

***Keywords*:**

Epoxy resin
silica fume
carbon fiber
composite
hybrid

ARTICLE INFO

Article history:

Received 24 January 2017
Accepted 01 June 2017
Available online 11 March 2018

ABSTRACT

A composite material has been prepared using epoxy resin as a matrix, reinforced with silica fume, carbon fiber, and their hybrid (mixture of silica fume and carbon fiber). Samples were prepared in a fabricated mold with dimensions according to the American Standards for Testing and Materials (ASTM). The additions of silica fume, carbon fiber, and mixture of them were with weight ratios of 0.5, 1, 1.5, 2, 2.5 and 3 wt.%. Properties of this composite material are determined; hardness, compression, and ultrasonic. The results showed that the mechanical properties increases with increasing of silica fume ratio up to 2 wt.%, and for higher than of 2 wt.% they were decrease, whereas the addition of carbon fiber and mixture of carbon fiber with silica fume powder correspondingly enhances the properties up to 2 wt.% and fixed on its values.

DOI: http://dx.doi.org/10.25130/tjes.25.1.11

Tikrit Journal of Engineering Sciences Tikrit Journal of Engineering Sciences Tikrit Journal of Engineering Sciences Tikrit Journal of Engineering

تقويـة الايبوكسـي بغبار السـيليكا وألياف الكاربون

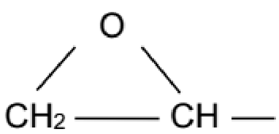
الخلاصة

تم تحضير ماده متراكبة باستخدام راتنج الايبوكسي مع كل من غبار السيليكا وألياف الكاربون وهجينهما (مزيج كل من غبار السيليكا وألياف الكاربون) كمواد تقوية وبنسب وزنيه قدرها 0.5، 1، 1.5، 2، 2.5، 3 %. حضرت العينات في قوالب اعدت لهذا الغرض بحسب المواصفات الأمريكية القياسية لاختبارات المواد. أظهرت النتائج العملية تحسنا في كل من الصلادة ومقاومة الانضغاط وتجانساً أكبر في البنية الفيزياوية عند إستخدام غبار السيليكا ولغاية 2 % وزنا وبعدها تبدأ بالهبوط. أما عند استخدام ألياف الكاربون ومزيج كل من ألياف الكاربون وغبار السليكا فإن الخواص تتحسن أكثر وبصورة متماثلة ولغاية 2% وزناً وتثبت بعدها.

1. INTRODUCTION

Owing to its inherent brittleness (derived from a highly cross linked structure) epoxy resins are used as a matrix phase in conjunction with other material; dispersed phase (reinforcement) to combine the advantage, of their properties in a composite material with an extended engineering applications.

The term epoxy resin describes a wide range of thermosetting polymers in which the main cross linking occurs through the reaction of an epoxide group. In general, an epoxy resin can be thought of as a molecule including a three membered ring, comprising of two carbon atoms and one oxygen atom [1].



Epoxy group

The composite materials are used due to their characteristics structure, besides to physical (electrical, thermal, etc.) and mechanical properties (hardness, tensile strength, etc.), which make them of wide range applications. Composite materials are usually optimized to obtain a particular balance of properties for a specific application [2].

Saavedra et al. [3] observed different trends to the effect of fumed silica contents above and below 30 wt % on the epoxy resin. Singla and Chawla [4] found that the compression strength increases with increasing fly ash particles in epoxy resin, and after reinforcing glass fiber both compressive and impact strength has been increased. Ruban et al. [5] indicated that the unsaturated polyester into epoxy resin bettering the impact strength. Significant enhancement in the impact strength, tensile properties, and flexural properties are noticed in the unsaturated polyester – epoxy mixes with rise in the percentage of amine – modified nanosilica particles. The results of Al- Khfaji [6] showed the values of hardness increased with volume fraction of boron powder in polyester resin, the best values

* *Corresponding author: E-mail* : amer.h.m.altaee@gmail.com

of impact strength and modulus of elasticity present at 4 %. Saleh et al. [7] uses fly ash and silica fume with epoxy resin and noticed an increase in compression strength, tensile strength, decrease in bending strength, and nearly no effect on the hardness. Vikram et al. [8] found that the flexural strength, flexural modulus, tensile strength and modulus were grown correspondingly up to 5 wt % for 2 cm of carbon fiber length reinforced epoxy and reduced with more addition of fiber content. The inclusion of carbon fiber with glass fiber in hybrid composites significantly enhanced the ultimate tensile strength, yield strength and peak load of the composite [9].

This work aimed to experimentally explore the effect of addition of silica fume (SF), carbon fiber (CF), and with their hybrid i.e., mixture of (SF) with (CF) reinforced epoxy resin (EP) matrix on some properties (hardness, compression strength, and ultrasonic) of the composite produced.

2. MATERIALS AND EQUIPMENT USED

2.1. Materials

2.1.1 Epoxy

Epoxy (EP) resins are a type of thermoset polymers broadly employed in a framework where they give a peculiarly composite application due to their excellent properties that are unobtainable with other thermoset polymers.

The EP resin used in this study is Quickmast 105 manufactured by Don Construction Products (DCP) with technical properties given in Table 1.

Table 1
Technical properties of EP resin used [10].

Compressive strength	≥ 70 MPa at 7 days at 25 ºC
Flexural strength	≥ 45 MPa at 25 ºC
Tensile strength	≥ 25 MPa
Pot life	50 – 70 min. at 25 ºC
Density	1.1 ± 0.05 g / cm^3
Dynamic viscosity	3 – 5 poise at 25 ºC 1 – 2 poise at 35 ºC

2.1.2. Silica Fume

Silica fume (SF), also known as micro-silica, is obtained as byproduct in production of silicon alloys such as ferromagnesium, ferrochromium, ferromanganese and calcium silicon. SF is also obtained as a byproduct of the reduction of high-purity quartz with coal in electrical furnace in the production of ferrosilicon alloys and silicon [11]. Commonly SF is added to the concrete to enhance its properties, where the SF showed improvement in bond strength, compressive strength, and abrasion resistance; on the other hand, SF decreases permeability; and wherefore helps in lowering the corrosion of reinforcing steel. SF is selected as a reinforcement in this study due to its very small particle size (less than 1 µm), which in turn gives very large specific area (2 × 10^4 m^2 / kg) which leads to usage as a good binder, and low cost. Table 2 gives the chemical composition of silica fume used in this work which is applicable to the American Concrete Institute (ACI).

Table 2
Chemical composition of silica fume used [12].

Composition	Wt %
Silica	98.87
CaO	0.23
K_2O	0.08
Al_2O_3	0.01
MgO	0.01
Fe_2O_3	0.01

2.1.3. Carbon fiber

Due to its excellent properties (high strength, high stiffness, chemical resistivity, low coefficient of thermal expansion, and light weight) carbon fibers are used in this study. Carbon fiber (CF) of Toray industries is used to embedding as reinforcement fiber in 0.5, 1.0, 1.5, 2.0, 2.5 and 3 % wt. Table 3, gives physical and mechanical properties of CF used.

Table 3
Physical and mechanical properties of CF used.

Property	**Value**
Density	1.5 g / cm3
Elongation	2 %
Carbon content	92.5 %
Tensile strength	3500 MPa
Yong's modulus	225 GPa

2.2. Equipment

2.2.1. Hardness Tester

Hardness Shore D instrument (Qualitest HPE) with a steel needle pin breakthrough the material, used for estimating the hardness of the composite.

2.2.2. Compression Strength Tester

Compression strength testing machine is of Tinius Olsen (universal test) H 100 KU. The compressive strength is calculated from the load of crushing divided by the area over which the load is strikes. Results of compression strength is a mean of six cubed shape specimens at the end of the ageing time.

2.2.3. Ultrasonic Tester

Ultrasonic instrument (Proceq, Pundit Lab., Switzerland made) is of pulse echo type employing “A” scan presentation, competent of receiving and producing frequencies between 1 and 5 MHz as a minimum.

3. EXPERIMENTATION

3.1. Preparation the Composite Material

The composites are fabricated from epoxy 105 which is a two component low viscosity epoxy resin system (Quickmast 105 resin and hardener of Don Construction Product) as a matrix material together with either of SF powder, whiskers of CF, and mixture of SF with whiskers of CF (hybrid) as a reinforcement by blending the two (matrix and reinforcement) after weighing the desired quantities in request weight percent (0.5, 1, 1.5, 2, 2.5, & 3 %) using digital balance (of four digit).

4. EXPERIMENTAL RESULTS AND DISCUSSION

4.1. Hardness Test

The results of hardness test for the EP with SF, carbon fiber, and SF plus CF are shown in Fig. 1.

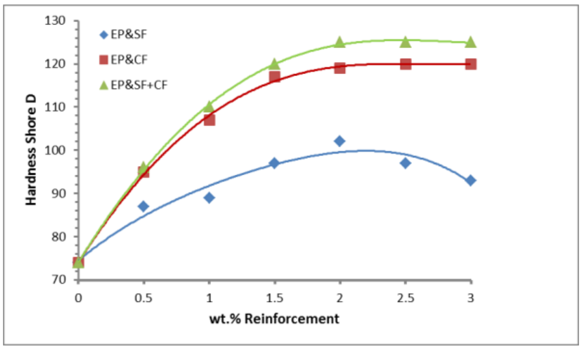


Fig. 1. Effect of reinforcement (wt%) on hardness of the composites.

Hardness increase as SF ratio increase up to certain limit as shown in Fig. 1 where the hardness reaches the highest value at 2 wt %, which could be attributed to the very small size of SF particle (0.6 – 1 µm), where these particles occupy the EP spacing completely and for higher ratios it will lead to drop in mechanical properties, which could be attributed to coalescence of SF particles.

Fig. 1 also indicates that the hardness increases with increasing the ratio of CF and SF plus CF correspondingly but with CF it is higher than that for SF plus CF and fixed at 2 wt % and thereafter, where the CF balanced the drop attained with using SF alone.

4.2. Compressive Test

The results of compressive test for the EP with SF, CF, and SF plus CF are shown in Fig. 2.

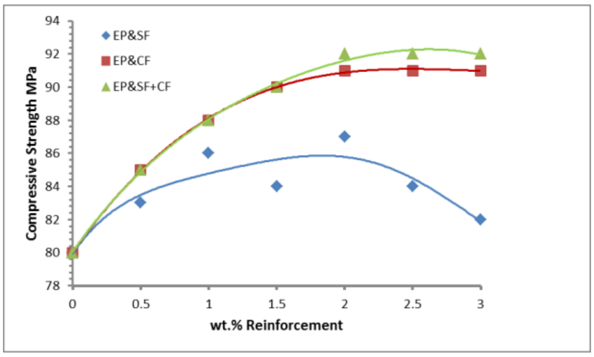


Fig. 2. Effect of reinforcement (wt%) on compressive strength of the composites.

Compressive test is considered as one of most important test to measure the mechanical properties, Fig. 2 shows that the value of compressive strength increase as the ratio of SF increases up to 2 wt % and thereafter will decrease, i.e. the compressive strength at 2wt % considered the best addition because it occupies all spacing and give high mechanical properties.

Fig. 2 also reveal that the compressive strength increases as increasing the ratio of CF and SF plus CF correspondingly but it with CF is more than that for SF plus CF and fixed at 2 wt % and thereafter, which due to the high stiffness and strength of carbon CF.

4.3. Ultrasonic test

The result of ultrasonic test for the EP with SF, CF, and SF plus CF are shown in Fig. 3.

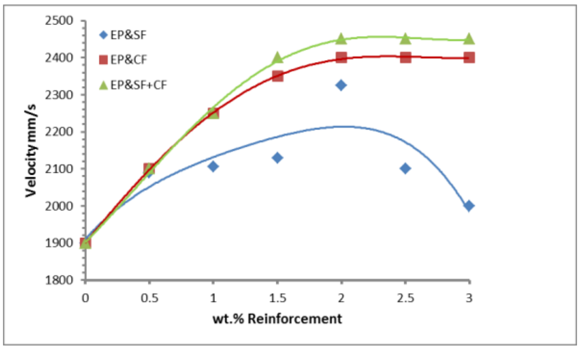


Fig. 3. Effect of reinforcement (wt%) on velocity of ultrasonic wave in the composites.

It is known that the velocity of ultrasonic wave measured in device represent wave velocity transmitted per distance unit of sample being examined, the results showed that for different additions, result appeared close in velocity except at around 2 wt % in which the increase tremendously, due to this ratio caused more homogeneity in the composite.

Fig. 3 also exhibit that the velocity increases as increasing the ratio of CF and SF plus CF correspondingly but it with CF is more than that for SF plus CF and fixed at 2 wt % and thereafter, since CF are dispersed uniformly into the matrix EP.

5. CONCLUSIONS

SF, CF, and SF with CF reinforced EP composites were synthesized with 0.5, 1, 1.5, 2, 2.5, & 3 wt %; the following conclusion remarks could be withdrawn:

1. Increasing SF ratios lead to increase the hardness, until 2 wt %, after this ratio the hardness decreases. While the increase in hardness with CF and mixture of SF with CF, is fixed at 2 wt % and thereafter.
2. Increasing SF causes an increase in the compression strength until 2 wt %, then the compression strength decreases. Whilst increase in compression strength with CF and mixture of SF with CF, is fixed at 2 wt % and thereafter.
3. From the ultrasonic test appear that the wave transmission velocity increase with the increase of additives ratios of SF and after 2 wt % it will decrease. While the increasing with CF and mixture of SF with CF, is fixed at 2 wt % and thereafter.

REFERENCES

[1] Augustsson C. NM Epoxy handbook. 3rd ed., Production Nils Malmgren AB; 2004.

[2] Jones RM. Mechanics of composite materials. 2nd ed., USA: Taylor & Francis; 1999.

[3] Saavedra JT, Beceiro JL, Naya S, Gracia C, Artiaga R. Controversial effects of fumed silica on the curing and thermo-mechanical properties of epoxy

composites. *eXPRESS Polymer Letters* 2010; **4** (6): 382-395.

[4] Singla M, Chawla V. Mechanical properties of epoxy resin-fly ash composite. *Journal of Minerals and Materials Characterization & Engineering* 2010; **9** (3): 199-210.

[5] Ruban YJV, Mon G, Roy DV. Mechanical and thermal studies of unsaturated polyester-toughened epoxy composites filled with amine-functionalized nanosilica. *Applied Nanoscience* 2013; **3** (1): 7-12.

[6] Al-Khafaji RS. Mechanical and electrical behavior of polymer matrix composite and their hybrids reinforced with carbon black-boron particles. *Journal of Al-Nahrain University* 2013; **16** (3): 171-177.

[7] Saleh NA, Al-Maamori MN, Al-Jebory MB. Evaluating the mechanical properties of epoxy resin with fly ash and silica fume as fillers. *Advances in Physics Theories and Applications* 2014; **30** (1): 1-7.

[8] Vikram A, Murthy VN, Murthy CBN. Mechanical and thermal properties of carbon fiber / epoxy composites with different fiber orientation. *International Journal & Magazine of Engineering, Technology, Management and Research* 2015; **2** (7): 1394-1403.

[9] Jagannatha TD, Harish G. Mechanical properties of carbon / glass fiber reinforced epoxy hybrid polymer composites. *International Journal of Mechanical Engineering and Robotics Research* 2015; 4 (2):.

[10] Internet source: http://dcp.bg/index.php?lng=en&p=prod1211

[11] Siddique R, Khan MI. Supplementary cementing materials. Springer Verlag Berlin Heidelberg; 2011.

[12] Idorn G M. Concrete progress – from antiquity to third millennium. Thomas Telford; 1997.