A Study of Bending Properties of Unsaturated Polyester/Glass Fiber Reinforced Composites

Estabraq T. Abdullah
Department of Physics, College of Science, Baghdad University.
E-mail: estabrak_talib@yahoo.com.

Abstract

In this study two commercial types of reinforced glass fibers were studied: chopped and 0/90 fiber glass composted with unsaturated polyester resin. The composites were prepared by hand lay-up method in three layers. The flexure properties were studied by using three-point bending test. The results showed that pure unsaturated polyester UPE is fractured when it reach the maximum point. Different behavior was shown for the fiber/polyester composite depending on the type of the fiber. The damage causes by the applied stress was appeared by photographs. In all samples the matrix cracking occur in the lower face of the specimen followed by fiber fracture due to the bending stress.

Keywords: unsaturated polyester, glass fiber, flexure testing.

Introduction

The main important industrial materials for the last 30 years are composite materials, [1]. The simplest definition of composite materials is mixing two or more materials to produce a new material which cannot be reversed. They characterized by stiffness, sufficiently strong, low cost, high temperature performance, electrical properties and simple manufacturing principles, [1, 2]. Also it can be classified into three types according to the types of matrix material: polymer, ceramic and metal, and according to their geometry into fibrous, particulate and laminated composites, [3]. Such materials are components of two phases: matrix phase, which is continuous and surrounds the dispersed phase (the other phase). The main work to the matrix phase is to bend the fibers together and act as a medium which disturbed the external applied stress to the fibers only a small portion will get through to the matrix phase, [4]. The most important polymer in glass fiber reinforced composite is unsaturated polyester. In the last 40 years glass fiber/ polyester conceders as one of the most famous composites because of its reasonable mechanical properties, low cost and easily fabrication techniques which include: spray, hand lay up reactive injection modeling and resin transfer, [3-5]. The unsaturated polyester / glass fiber reinforced begin to use during the World War II in attend to produce protective housing for radar equipment, now a days it entered almost every thing including marine transportation, contraction, electrical and industrial. These composite materials had continuous to improve in their mechanical properties especially flexural and tensile strength, [6].

Bending stresses are important in structure tests because of variety of loading situations in service. It determines the behavior and properties of the structure. Many parameters should be concerned test data.

The current work attempts to study the flexure behavior of glass fiber-reinforced polyester composite. In this study, polyester matrix reinforced with chopped and 0/90 mats glass fiber composites were developed with different content of different volume fraction of fiber.

Experimental Work

1-Materials

The matrix used in this study was unsaturated polyester UPE (SIR Saudi Arabia). It is viscous liquid, transparent, thermosetting polymer type. The liquid converts to solid by adding hardener additives methyl-ethyl-ketone-peroxide (MEKP), which is transparent liquid with 2% for each 100gm of UPE at room temperature.

Two types of glass fiber were used chopped and continuous mat (LTD, UK) as strengthening for the UPE with thicknesses (0.45, 0.29) mm respectively. These fibers are immersed in an orderly manner in form of regular layers.

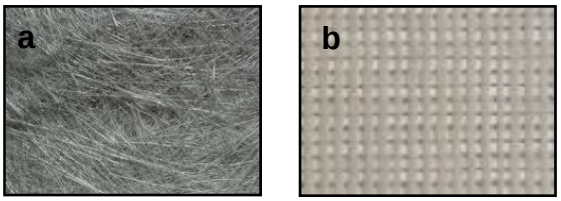

Fig.(1) a- chopped b-0/90 class fiber mates.

2-Sample Preparation

Hand layup (HLU) technique was used to produce three layer composites. First the UPE liquid mix with MEKP hardener 10% liquid. The mixture reinforced by glass fiber with different values of volume fraction. The glass mould of frame was (15×15×4) cm used for casting the sheet of composite material. Wax was fixed on the inner mould faces before casting to ensure the releasing of casting composites and having smooth faces. Samples were left to cure for two days at room temperature. The specimens were cut out of the molds with sample dimensions in accordance with the related international, ASTM standard 790-D).

3-Flexural Strength

Three-point Bending tests was used to study the flexural of the specimens and it was carried out by using Instron universal testing machine of 5 kN full scale load capacity according to ASTM standard (D-790). The five rectangular specimens have frame dimensions (15×15) cm. Flexural strength of the composites was calculated according to [6]

$$\sigma_m = \frac{3FL}{2bd^2} \quad \text{.....(1)}$$

where F: is the applied central load (N), L: support span, b and d: width and thickness of the specimen (mm). Elasticity modulus was calculated according to

$$E = \frac{L^3 m}{4bd^3} \quad \text{.....(2)}$$

where m is the slope of the tangent to the initial straight line portion of the force-deflection curve. The maximum tensile strain was calculated according to

$$\varepsilon = \frac{6Dd}{L^2} \quad \text{.....(3)}$$

D is the deflection beam at a given point on the load –deflection data.

The volume fraction (amount of fiber) was calculated according to:

$$V_f = \frac{M_f}{M_f + (1 - M_f)\frac{\rho_p}{\rho_m}} \quad \text{.....(4)}$$

where ρ_m and ρ_f: are the density of the matrix and glass fiber respectively ($g.cm^{-3}$).

Results and Discussions

The mechanical properties of the materials are affected by many factors including: fiber type, volume fraction, direction of the fiber, specimen thickness. The results in Fig.(2) show that the force-deflection curves for composites. There are two noticeable regions: the elastic region, and plastic region, it shows that the molecules slip passes each other normally to a small extent. After that point the craze show up which the material begin to deform numerous micro voids, [3].

Due to the initial non-linearity region is basically the deformation of the matrix resin. So linear slope characteristic is reflects the deformation of the glass fibers.

The results of pure UPE Fig.(3) shows that the samples fractured once it reached the maximum load, while the composite samples show a different behavior according to the type of fiber although they where common to have a linear behavior initially and after noted displacement, where the curve began to fluctuate. For the samples X2 and X3 shows a difference in the flexure properties the reason could be attributed to the ability of chopped fiber glass to absorb more ester monomers than 0/90 mate that lead to higher plastic content [8], and that was effected in the fiber type behavior of samples x4 and x5. Such behavior inverse on the magnitude of maximum stresses, yield strength, and young modulus as shown in Table (1).

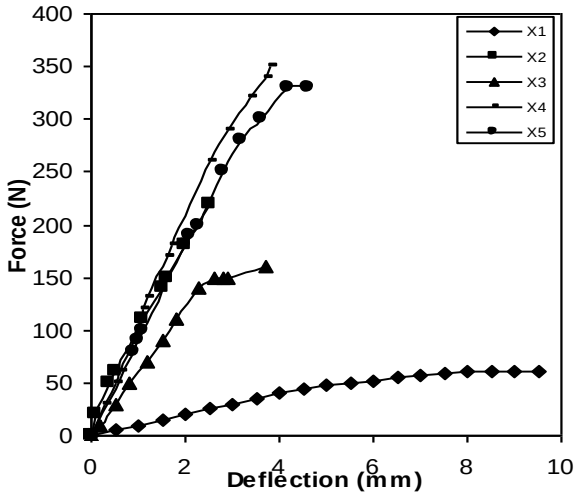

Fig.(2) Force-deflection curves for UPE and glass fiber composites.

Table (1)
Values of Ultimate Max. stresses σ_m, Yield Stresses and Young modulus for UPE composites.

Code	*Definition*	*Volume fraction*	*Max. Stress σ_m (MPa)*	*Young modulus (MPa)*	*Yield strength (MPa)*
X1	pure	0.1265	0.2245	9.8182	148
X2	3 layer random	0.1528	0.0819	85.103	158
X3	3 layer 0/90	0.1531	0.0489	61.085	165
X4	Random+ 0/90 + random	0.1515	0.1051	107.59	195
X5	0/90+random+0/90	0.1467	0.0675	90.369	175

The crack is initiated in the outer layer of the samples. The mechanism of failure is occurring when the critical state of stress in samples is reaching that will cause the appearance of critical value of crack and its unstable growth. The position of critical crack is associated with the fiber matrix debonding after which the fibers cracked. When the first break in the outer layer appeared it follows by more broken fibers (which was debonded and pulled out from the matrix). The crack propagates from the outer to the inner surface sample in transversal direction. The crack and delaminating appears in the samples as a result of shear stresses in the layers which is characteristic of bending test [9]. Fig.(3) shows the crack take place in the tested samples, which shows there is no abruption fracture is noted.

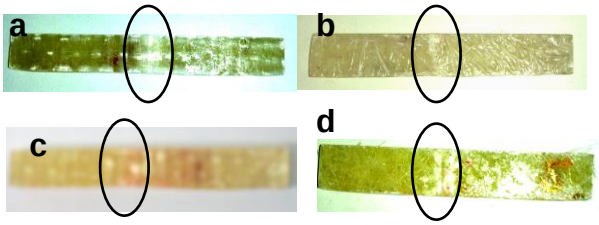

Fig.(3) Photographic picture show the fracture surface in (a) X2, (b) X3, (c)X4, and (d)X5.

Fig.(3) shows that the presence of fibers was effected by rapid propagation of brittle cracks to occur. So we can say that glass fiber service as a barrier to crack propagation [9, 10].

The function of polyester in the composite is to bind fibers together so it behaves as the medium which transmitted and distribute the applied field to the fiber. While the crack is propagation a portion of the applied load is transfer from the polyester matrix to the fibers. While a small part from the applied load is still in the polyester matrix.

Such behavior proves the decreasing of brittleness of polyester matrix needs the help of glass fiber.

Conclusions

The influence of reinforced type of fiber was notice. The random composite was notice to have young modulus, max. stress, and yield strength higher by comparing with the 0/90 composite, the same behavior was notice for X 4 by comparing with X5, since the chopped fiber glass to absorb more ester monomers than 0/90 mate that lead to higher plastic content . The photograph show the initiation of the cracks for all samples which indicates was notice in X2 and X4.

Acknowledgments

The author would like to thank both Asst. Prof. Zainab Raheem and Mohammed Kadhum, Physics department, College of Science, Baghdad University.

References

[1] Santiuste C., Sanchez-Saez S. and Barbero E., "Residual flexural strength after low-velocity impact in glass-polyester composite beams", composite structures, 92, 25-30, 2010.

[2] Hameed Awan G., Ali L., Ghauri K. M., Ramzan Engr. and Ehsan Engr. "Effect of various forms of glass fiber reinforcements on tensile properties of polyester matrix composite", Journal of Faculty of Engineering & Technology, 16,33-39, 2009.

[3] Jadah A., "Investigation of some mechanical properties of sawdust and chopped reeds/UPE composite", M.Sc., Baghdad University, 2011.

[4] Askeland D., "The science and engineering of materials", 2nd edition Chapman & Hall Company, UK, 15-17, 1990.

[5] Naga V., Ashok M., Ramachandra G., Noorunnisa P., Mohan M., and Chakradhar K., "Tensile and flexure properties of sisal/glass fiber reinforced hybrid composites", international J. Macromolecular Sci., 1, 19-22, 2011.

[6] Davallo M. and Pasdar H., "Comparison of Mechanical Properties of Glass-Polyester Composites Formed by Resin Transfer Molding and Hand Lay-Up Technique", International Journal of Chem. Tech. Research, 1**,** 470-475, 2009.

[7] Segovia F., Salvador M.D., Amigo V. and Bloem C., "Shear strength characteristics in aged polyester-glass fiber composite", 12th International Conference on Composite Materials, pdf num. 125". Paris, July 5th - 9th, 1999.

[8] Flexural properties of unreinforced and reinforced Plastics and Electrical Insulation, Annual Book of ASTM Standard, ASTM D-790-81, 08.01, 403-405, 1992.

[9] Varga CS., Miskolczi N., Bartha L. and Lipoczi G., "Improvement the mechanical properties of glass-fiber-reinforced composites by modification of fiber surface", materials and design, 31, 185-193, 2010.

[10] Stevanovic M. and Stecenko T., "Tensile and flexure macromechanical characteristics of glass/polyester composite", J. Serb. Chem. Soc. 57, 451, 1992.

[11] Leonrd L., Wong K., Low K., and Yousif B., "Fracture behavior of glass fiber-reinforced polyester composite", Proc. IMechE, 223, part L: J. Materials: Design and Application, 2011.

الخلاصة

تم في البحث الحالي دراسة نوعين تجارين من الالياف الزجاجية المدعمه: المقطع والمنتظم (٩٠/٠) المخلوط مع البولي استير المشبع. حُضِرت المتراكبات بطريقة القولبة اليدوية بثلاث طبقات. دُرِست خصائص الثني باستخدام اختبار الانحناء ذي الثلاث نقاط. أظهرت النتائج ان العينة النقية تتكسر فور الوصول الى اعلى نقطة. وقد لوحظ سلوك مختلف لمركب الياف/ البوليستير اعتماداً على نوع الالياف. وضحت الصور الفوتوغرافية الاضرار التي سببها الاجهاد. يحدث الكسر لكافة العينات في الوجه السفلي للعينه تليها كس للالياف بسبب اجهاد الانحناء.