



Effect of Fiber Volume on The Flexural Strenght of Steel Fiber Reinforced Polyester Resin Composite

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Abstract

The aim of this study is to determine the flexural properties of steel fiber as a metal fiber and polyester resin as a matrix. The steel fibers were added to polyester resin at the various fiber volume fractions of 5, 10, and 15% steel fiber, and with different fiber orientations such as woven steel fiber type (0-45) ° and woven steel fiber type (0-90) ° indicate. Hand layup processes in these experiments were used to produce specimens test with the curing time of 24 hr. for the composite at room temperature. The results show that the flexural strength and flexural modulus values for 15 % vol.of woven steel fiber composite type (0-90) ° are (210MPa) and (2.29GPa) respectively. The results above indicate that the woven steel fiber (0-90) ° has a better bonding between its fiber and matrix compare to woven steel fiber type (0-45) °.

Keywords: Polyester, Steel fiber, Flexural strength, Composites material

تأثير الكسر الحجمي في متانة الالتواء لمتراكبات البولي استير المدعم باللياف الحديد

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الخلاصة

الهدف من هذه الدراسة هو تحديد خواص الالتواء لالياف الحديد كالياف معدنية وراتنج البولي استير كمادة اساس . الياف الحديد اضيفت الى راتنج البولي استير بكسور حجمية مختلفة هي 5, 10 و 15% , مع اختلاف في اتجاه الالياف مثل حصيرة الالياف نوع (0-45) ° وحصيرة الالياف نوع (0-90) ° . تم تصنيع الواح من المتراكبات بطريقه التصنيع اليدوي مع زمن تصلب مقداره 24 ساعه بدرجه حرارة الغرفة. اظهرت النتائج قيم متانه الالتواء ومعامل الالتواء للكسر الحجمي 15% لمتراكبات حصيرة الياف الحديد نوع (0-90) ° هي (210MPa) و(2.29GPa) على التوالي. وبينت النتائج اعلاه ان حصيرة الالياف من نوع (0-90) ° تمتلك اليافها ترابط افضل مع المادة الاساس مقارنة لحصيرة الالياف نوع (0-45) ° .

Introduction

Unsaturated polyester is widely used for pipes, tanks, boat hulls, architectural panels, car bodies, panels in aircraft, and stackable chairs [1,2]. Many attempts have been made to improve the structural properties of polyester. One of the critical issues in unsaturated polyester is the poor mechanical resistance for cracks because it is difficult to produce flaw-free materials. To overcome the above problem; reinforcements (particles, fibers, laminates, etc.) have been used for polyester. Fiber reinforced composite materials are an important class of engineering materials. They offer outstanding mechanical properties, unique flexibility in design capabilities and ease of fabrication. Composites using high strength

fibers such as graphite, aramid, aluminum, and glass are commonly used in broad range of applications from aerospace structure to automotive parts and from building materials to sporting goods [3].

Several analyses have been carried out to study the effects of steel fibers on the physical properties of polymeric composites. Arikian et al. [4] produced Steel fiber reinforced particle-filled polymer composite beams with different weight fractions of steel fiber with varying notch-to-depth ratios $a/W = 0.1, 0.2, 0.3$ and 0.4 . They determined critical stress intensity factor by using several methods: initial notch depth method, compliance method and J-integral method.

Cheng et. al.[5] developed a method for fabricating conductive knitted fabric reinforced composite materials and determined their electro-magnetic shielding effectiveness (EMSE). It has been found that knitting stiff copper wires and glass fibers is feasible, by using the uncommingled yarn technique.

Hathal et al. [6], prepared a hybrid composite material contains a matrix which is Epoxy resin (EP) natural and fabricated fibers (Kevlar fiber + Woven and short glass fiber + Palm fiber + Metal fiber), the results obtained showed good improvement of thermal conductivity values of the composite material consists of metal wires as result of improve the thermal conductivity.

The objective of this work is to investigate the flexural properties of polyester composites based on woven steel fiber; two types of woven steel fiber were chosen: type (0-45) ° with volume fraction 5%, and type (0-90) ° with volume fractions 5%, 10%, 15%.

Theory

Flexural strength is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a rod specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique. When an object is bent, Figure.1, it experiences a range of stresses across its depth. At the edge of the object on the inside of the bend (concave face) the stress will be at its maximum compressive stress value. At the outside of the bend (convex face) the stress will be at its maximum tensile value. These inner and outer edges of the beam or rod are known as the "extreme fibers".

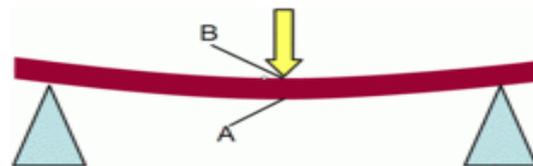


Figure 1-Beam of material under bending. Extreme fibers at B (compression) and A (tension)

The tensile and compressive forces operate on opposite sides of the neutral axis which constitute a bending moment (M), that require to bend the specimen to a radius of curvature stiffness in bend. This is usually defined as the bending moment required to produce unit curvature ($1/R$) of the specimen and called its flexural rigidity [7]

$$\text{The fluxral rigidity} = \frac{M}{1/R} = MR \quad (1)$$

R = Radius of curvature stiffness in bend.

The tensile and compressive force is obviously related to E , young modulus of the material according to theory of bending, the flexural rigidity could be

$$MR = EI \quad (2)$$

I is the second moment of area for rectangular beam the flexural strength [8]

$$S = M / M_m \quad (3)$$

M_m : the moment of resistance

$$M = \frac{PL}{4}$$

and

$$M_m = \frac{bd^2}{6}$$

$$S = \frac{3PL}{2bd^2} \quad (4)$$

Where S is flexural stress, P the load applied to a sample of support span L, width b, and thickness d.

The maximum strain in the outer fibers which happen in the midpoint of the specimen is given by

$$r = \frac{6Dd}{L^2} \quad (5)$$

where r is the flexural stain, D the maximum deflection at its mid-point.

The flexural modulus is a measure of the stiffness during the first initial part of the bending process. The deflection of the beam at its midpoint is given by

$$I = \frac{PL^3}{48EI} \quad (6)$$

$$I = \frac{Pd^3}{12} \quad (7)$$

So the following equation is used to determine Young's modulus of the specimens

$$E = \frac{L^3}{4bd^3} \cdot \frac{P}{D} \quad (8)$$

Experimental Procedure Materials

Unsaturated polyester (UPE) resin (containing styrene as a cross – linking agent), was used as resin for the current work and was supplied by Saudi industrial resin CO. LTD. For 100 gm. of UPE resin were mixed with 0.5 gm. of cobalt naphthenate as accelerator and 2 gm. of Methyl Ethyl Ketone Peroxide (MEKP) as hardener. The woven steel fibers were procured from a local supplier in Baghdad-Iraq.

Fabrication of Composite Plates

The composites were made by hand lay-up technique. The mould used for the composite of size 200×200×3 mm³ was made of glass. Glass silicon was used for joining frames. The woven steel fiber was cut based on the mould size, at the various fiber volume fractions of 5, 10, and 15% for woven steel fiber type (0-90) ° and 5% fiber volume fraction for woven steel fiber type (0-45) °. Then the fiber was placed over the transparency plastic sheet in the bottom of the mould which has been prepared before. Initially polyester and hardener were mixed together based on the weight percentage to form a matrix, then the matrix was poured over the fiber and compressed and distribute evenly until it achieved thickness. The curing time was around 20–24 hours until the composite plate dried, if applied at the room temperature condition of 25-30 °C.

Flexural Tests

Flexural tests were performed on the Instron machine using the 3-point bending method and with maximum load of 5 kN according to ASTM standard (D-790) [9], the test was with cross head speed of 0.5mm/min. The specimen dimensions were 60 mm (L) x 25 mm (b) and had 3 mm (d) thickness. Each test was repeated three times for each type of specimen, and the average values were determined. The load P and the corresponding displacement were recorded.

Results and Discussion

Mechanical properties of the fiber composites depend on several factors such as the stress–strain behaviors of fiber and matrix phases, the phase volume fractions, the fiber volume fraction, the distribution and orientation of the fiber relative to one another [10]. Figure 2 shows the typical flexural stress vs. strain curves for woven steel fiber type (0-45)° and (0-90)° composite with volume fraction of 5%. The trend is observed here whereby the woven steel fiber type (0-90)° composite has a superior flexural strength result compare to woven steel fiber type (0-45)° composite. The flexural strength values are dependent very much on the fiber orientation and the location of resin-rich areas. Therefore woven steel fiber type (0-90)° tend to give better strength due to their good fiber orientation, this result agree with other previous researchers[11]. The specimen test of woven

steel fiber type (0-45) ° composite is broken easily and could not resist bending. It is possibly because the orientation of woven steel fiber type (0-45) ° has caused many voids forms in the specimen curing process of composite materials.

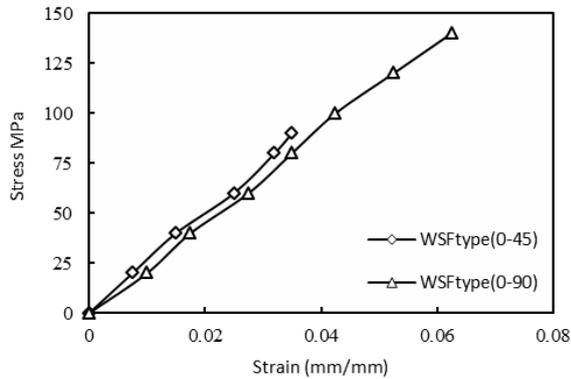


Figure 2- Flexural stress versus strain for woven steel Fiber type (0-45)° and (0-90)° reinforced polyester composite with volume fraction 5%.

Figure 3 shows the typical flexural stress vs. strain curves for net polyester and woven steel fiber type (0-90)° composite with different volume fractions (5,10,and15)%. The composite demonstrated slightly nonlinear behavior prior to sharp failure or fracture. This means that specimen deformed plastically immediate after elastic deformation. It can be seen from Figure 4 that flexural strength of the composites increased with increasing the fiber volume fraction. This is due to the fact that steel fibers strengthen the interface adhesion of resin matrix and fiber materials.

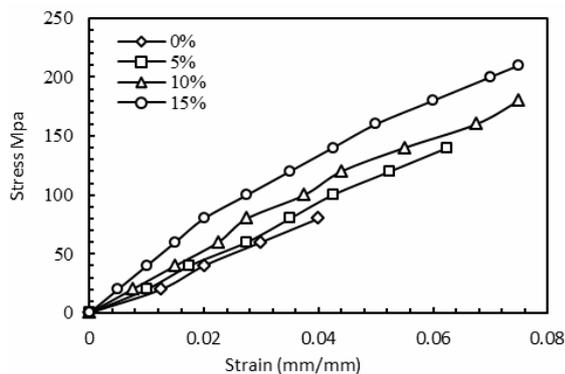


Figure 3- Flexural stress versus strain for net polyester and woven steel type(0-90) composite.

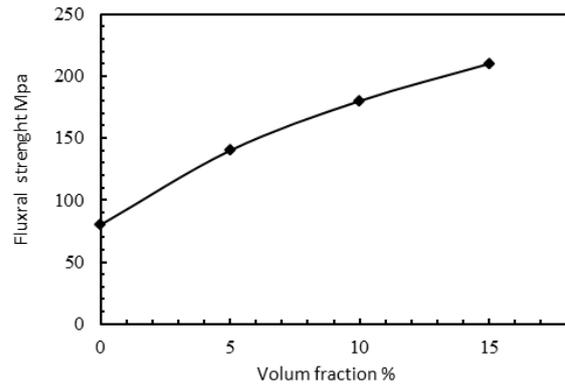


Figure 4- Flexural strength versus volume fraction of steel fiber.

The flexural modulus (Young modulus) was obtained from equation 8. The values of the flexural modulus were decreased with increasing steel fiber content as shown in Table 1, this attributed to increase of ductility with increases fiber content.

Table 1- Flexural Modulus for bending test for steel fiber reinforced Polyester.

Type of composite	Vol.% of woven steel fiber	E(Gp a)
net	0	3.12
(0-90)	5	2.82
	10	2.79
	15	2.29

Conclusions

On the basis of the experimental evidences, the conclusions are as follows: The results of flexural strength test of woven steel fiber type (0-90) ° reinforced polyester composites showed that the 15 vol. % fiber has the highest value compared to other fiber content. The flexural strength of woven steel fiber type (0-45) ° composite is lower comparing with woven steel fiber type (0-90) ° composite at the same volume fraction. The results of present study have showed that using woven steel fiber as a reinforcement agent for the polyester matrix could successfully develop a beneficial composite particularly in term of strong and rigidity.

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