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Effect of Water Absorption on Hardness Property for Epoxy Reinforced by Glass Fibers

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Abstract

This research includes studying the effect of water absorption on hardness properties for Epoxy reinforced with glass fibers .Composite materials prepared from the Epoxy resin as matrix reinforced by E-glass fibers [0 - 90o Woven Roving and Random] with volume fraction 25%.The shore D hardness of all samples investigated before and after immersion in water at room temperature . Results of the work show that the value of hardness which done at room temperature decreases with increasing the time of immersion in water . The weight of absorbed water increases with increasing the time of immersion in water specially in the first week .The quantity of absorbed water decreases or increases also according to kind and number of reinforcing layers of glass fiber .

Key words: Water Absorption , Hardness , Epoxy , Glass Fibers

Introduction

Epoxy resins reinforced with fiber glass have been well accepted as engineering materials for various applications , as a common feature of composite , anisotropy in mechanical properties was observed , which has high fractures strength and stiffness along the fiber strengthening component [1].

Epoxy resins have been better mechanical strength , chemical resistance , electrical insulating properties and environmental stability than those made with conventional unsaturated polyester [2,3].

Polymer matrix composites absorbed either by diffusion of water molecules directly or by transport of water through micro crakes or other forms of microdamage such as pores or small channels already present in to material expanded by water [4,5].Several researchers studied the effect of water absorption on the behavior of E-glass/ Epoxy composite as [6,7,8]

Han [9] has observed the effect of water on inter laminar fracture of E-glass/ Epoxy , he noticed that the fiber content ,fiber orientation and bonding between fiber / matrix caused slight discrepancy to the diffusion coefficient. Z. U. Hague and D. T. Turner [10] studied the influence of particulate fillers on the indentation hardness of glassy cross – linked network was decreased to minimum value by a low volume fraction (0.03 to 0.05) of each six fillers . This rigid particles varying in size and surface . This minimum effect was eliminated after specimens were more highly cross-linked by prolonged exposure to γ-rays .

These results are consistent with an earlier suggestion that filler particles act as stress concentrators which may increase localized plastic deformation and hence a decreased indentation hardness . In 1990 Iatin R. , Ravji D. , Ranjan G. [11], showed that the harness values measured on the glass fiber reinforced composites after immersion in (H2O, Acetone , 10% NaOH , 10% HCl) for seven days fell within the small range . This indicating no appreciable influence of the regents on the harness

Experimental

Material used

Matrix :Epoxy resin type (EP – 10) with density 1.2 gm/cm3 was used to fabricate the samples and the hardener material was added in order to solid it with ratio 1:3 of resin .

Reinforcing material :Uniform and random E-glass fibers were used as a reinforcing materials . they have density 2.58 gm/cm3 , young modulus 35 GNm-2 and tensile strength (100) MNm-2 .

preparation of samples :

Slates preparation : The glass slates were cut with dimensions (30 X 30) cm , thickness (6 mm) , clean by distilled water to remove the dirt and the dust present on the surface , and then the slates were put in the oven at temperature (50oC) in order to dry . Then we diffuse a wax on the hot glass slates to prevent adhesion between matrix and slates .

Hand lay-up method was used to prepare the samples because it is easy , simple and cheap. This method includes :

Cutting up many fibers laminates of E-glass with dimensions (20 X 20) cm using special scissors , and weight them by sensitive balance (Four digits) .

Calculating the fibers volume (Vf) by the relation :

$$V_f = \frac{W_f}{\circ_f}$$

Where Wf is the weight of fibers $\circ_f$ is the density of fibers

After knowing the weight and volume of the fibers , the weight and the volume of the matrix were calculated (matrix is consisting of Epoxy and hardener).

Epoxy and hardener were mixed very well to get homogeneity .Distributing the resin on glass slates covered with wax , then putting fiber glass laminates on the resin, finally we put the resin again on the fiber surface to cover it very well.

Putting the second glass slate which is covered with wax on the glass laminates , then put suitable load on the second glass slates and leave it for (24) hours to harden well.

After (24) hours , the load is lifted from the two glass slates , and we get one layer fiber glass campsite material . Repeat the above steps to get two or three layers specimens .

The volume fraction (V) was calculated by using the relation :

$$V = \frac{V_f}{(V_f + V_m)} \times 100\%$$

Where

V_f is the volume of fibers

V_m is the volume of matrix

Cutting up the samples :

All samples were cutting in the dimensions of (70 mm) length and (10 mm) width . the thickness depends on the number of layers in the sample .

Weight of samples :

Electronic sensitive balance (type Sartorius, 4 digit) was used to weight the samples before and after immersion in water.

The tests and used equipment :

. Hardness test :

Hardness is the resistance of a material to localized deformation [12] . Hardness measurements are widely used for the quality control of materials because they are quick and considered to be nondestructive tests when the marks or indentations produced by the test are in low stress areas [13] .

There many methods to test hardness as :

Moh's Hardness test.

Brinell Hardness test.

Rockwell Hardness test.

Barcol Hardness test.

Durometer Hardness test.

In this research Durometer Hardness test was used to test all samples before and after immersion in water for (14) days in room temperature .

hardness Equipment :

We used Durometer Hardness instrument by (shore D) that is fabrication by (time group Inc) company to execute the hardness test by wing pointed dibbing tool , which penetrate the material surface by the pressure applied on the instrument where the dibbing tool head touching quite the surface of the samples , then we see the value of the sample hardness recorded on the screen of the instrument .

Results and discussion :

Hardness test

Hardness give good idea about durability and coherence of the material mass by using small loads . Durometer instrument is used for this test . We took three readings for each sample to calculate the average .

The hardness values for the samples before and after immersion in water :

Table (1) shows the value of hardness before and after immersion in water for (14) days .

From this table (1) we showed hardness of all specimens decreased with increasing the time of immersion in water illustrated in figure (1) . This results are because of water penetration inside polymers decreasing the connection between molecules of polymeric and then softening of manufactured material. Composite materials reinforced with glass fibers had many channels and capillary tube which allowed for water molecules to penetrate inside the materials and acting along the interface between epoxy and glass fiber causing swells in the samples . Then the bonds between resin and fibers will break . So the strength of the composite material will decrease .

. Hardness of samples reinforced by uniform and random glass fiber :

Table (2) and table (3) show the relations between hardness and immersion time in water for samples reinforced by uniform (0 – 90)o and random glass fibers .

From these tables we showed that the hardness decrease with increasing immersion time in water at room temperature for different type and number of layers of glass fiber.

Results of tables (2) and (3) illustrated in figures (2) and (3) . From these figures we conclude that the hardness of unreinforced materials less than the reinforced materials . We think that this related to water absorption which decrease the connection between molecules and polymeric chains and increase the softening of

unreinforced materials (EP) . Also the effect of water absorption associated with the (phenolinether , Amino and hydroxyl) group tend to decrease the hydrogen bonding between of polymer chain which is reflected by platization of resin .

Also from tables (2) and (3) and figures (2) and (3) , we found that the hardness decreases with increasing the number of layers uniform glass fiber ,because reinforced materials with glass fiber had many channels and capillary tubes allowed for water molecules to penetrate inside the composite material . These channels and capillary tubes increase with increasing the number of layers . As the absorbed water center the resin and reach the fibers , it dissolves the surface to create an osmotic pressure which will rapidly deboned the whole fibers .

Water absorption test:

Electronic sensitive balance (for digit) was used to weight the sample before and after immersion in water for (14) days .

The quantity of absorbed water by samples , can be calculated according to following relation :

Weight of absorbed water = Weight the sample after immersion - the weight of dry sample .

Tables (4) and (5) show the weight of absorbed water for sample reinforced with different layers of uniform glass fiber and for samples reinforced with random glass fiber respectively .

From table (4) , we plot the relation between weight of absorbed water and immersion time for samples reinforced by different layers of uniform glass fiber as shown in figure (4) . We noticed from this figure that the unreinforced material absorb water less than the reinforced samples [14].

This belong to the fact that the unreinforced sample absorb water by diffusion process which depends on the change in the concentration Penetration of water depends on the interdistance between molecules which form the polymeric chain inside the sample . So the absorption of water by unreinforced sample decreases the bonding between molecules and polymeric chains and increase the softening of samples .

Also from figure (4) , we show that the quantity of absorbed water by reinforced samples increase with increasing the number of layers of uniform (0 – 90)o glass fibers , and with increasing the time of immersion in water at room temperature .

We thought that the reinforced samples have many channels help water to penetrate inside the sample . in addition to existence of interface between matrix and glass fibers which considered as capillary tubes for water transport and penetration inside the samples .

Table (5) shows the weight of absorbed water with immersion time for samples with different layers of random glass fibers . We plot these relation in figure (5) . We noticed from table (5) and figure (5) that the weight of absorbed water increases with increasing the number of layers of glass fiber and with increasing the time of immersion in water until (14) days . The explanation of this process like that for uniform glass fiber samples , but we noticed that the quantity of absorbed water less than for uniform glass fiber .

Conclusions :

Hardness decreases with increasing the time of immersion in water at room temperature until reach the saturation for samples unreinforced or reinforced with different layers of uniform (0 – 90) o or random glass fibers .

Hardness increases with increasing the number of layers fibers for all samples .

The quantity of absorbed water increases with increasing the time of immersion in water and with increasing the number of layers (uniform or random) glass fiber.

Unreinforced samples absorb water less than the reinforced samples .

Table (1) shows the values of hardness of samples reinforced by different layers of uniform and random glass fiber before and after immersion (14 days) in water at room temperature

Specimen No.	Type of specimen	Hardness as dry sample	Hardness after immersion (14 days)
1	Ep	75.52	38.21
2	Ep + 1 Layer Un G.f	80.21	53.01
3	Ep + 2 Layer Ra Un.f	84.16	57.7
4	Ep + 3 Layer Un G.f	86.63	65.23
5	Ep + 1 Layer Ra. G.f	79.00	50.2
6	Ep + 2 Layer Ra G.f	82.13	56.81
7	Ep + 3 Layer Ra. G.f	85.93	63.44

Table (2) shows the relation of hardness with the time of immersion in water for samples reinforced by different layer of glass fibers .

No.	Type	Hardness						
		Dry sample	1 day	3 days	5 days	8 days	12days	14days
1	Ep	75.52	60.01	52.03	49.7	45.01	40.25	38.21
2	Ep + 1 Layer Un G.f	80.21	69.71	61.61	59.41	56.75	55.3	53.01
3	Ep + 2 Layer Un G.f	84.16	71.1	66.73	65	61.75	58.48	57.7
4	Ep + 3 Layer Un G.f	86.63	80.01	76.31	73.43	71.11	66.73	65.23

Table (3) shows the relation of hardness with the immersion time for samples reinforced by different layers of random glass fibers .

No.	Type	Hardness						
		Dry sample	1 day	3 days	5 days	8 days	12days	14days
1	Ep	75.52	60.01	52.03	49.7	45.01	40.25	38.21
5	Ep + 1 Layer Ra G.f	79	69.21	58.11	56.71	53.42	52.31	50.2
6	Ep + 2 Layer Ra G.f	82.13	69.53	65.2	64.76	60.1	57.39	56.81
7	Ep + 3 Layer Ra G.f	85.93	81.21	74.1	71.55	69.42	65.56	63.44

Table (4) : shows the weight of absorbed water (gm) with immersion time for specimens with different layers of uniform glass fiber.

No.	Type	Weight of absorbed water					
		1 day	3 days	5 days	8 days	12 days	14 days
1	Ep	0.003	0.008	0.014	0.0181	0.0221	0.0241
2	Ep + 1 Layer Un. G.f	0.0101	0.0231	0.033	0.042	0.05	0.0551
3	Ep + 2 Layer Un . G.f	0.0121	0.028	0.0421	0.055	0.0641	0.0711
7	Ep + 3 Layer Un.G.f	0.0123	0.0411	0.0504	0.071	0.082	0.0851

Table (5) : shows the weight of absorbed water (gm) with immersion time for specimen reinforced with random glass fiber.

No.	Type	Weight of absorbed water					
		1 day	3 days	5 days	8 days	12 days	14 days
1	Ep	0.003	0.0081	0.014	0.0181	0.0221	0.0241
5	Ep + 1 Layer Ra. G.f	0.0036	0.0107	0.0178	0.0232	0.026	0.0281
6	Ep + 2 Layer Ra . G.f	0.0039	0.0135	0.0211	0.0261	0.0311	0.0321
7	Ep + 3 Layer Ra.G.f	0.004	0.0141	0.0244	0.0301	0.0351	0.0362

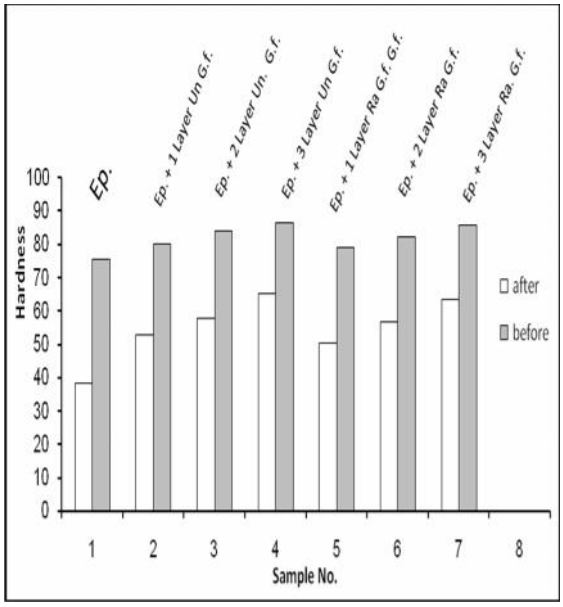

Fig. (1) : The relation between hardness and the type of reinforcing before and after immersion (14 days) in water

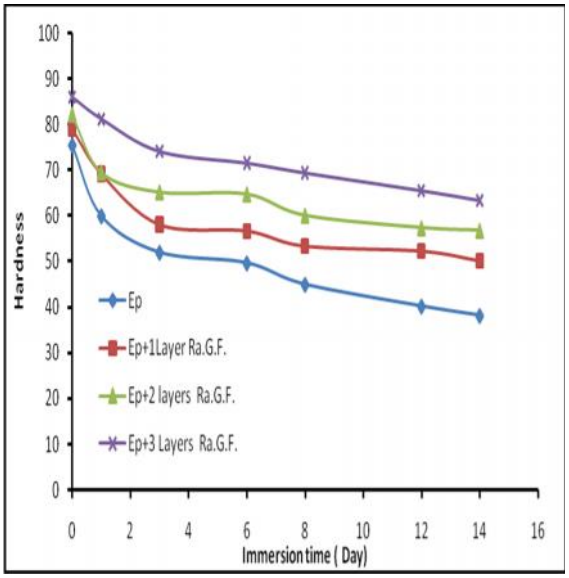

Fig. (3) : The relation between hardness and immersion time in water for samples reinforced with different layers of random glass fiber.

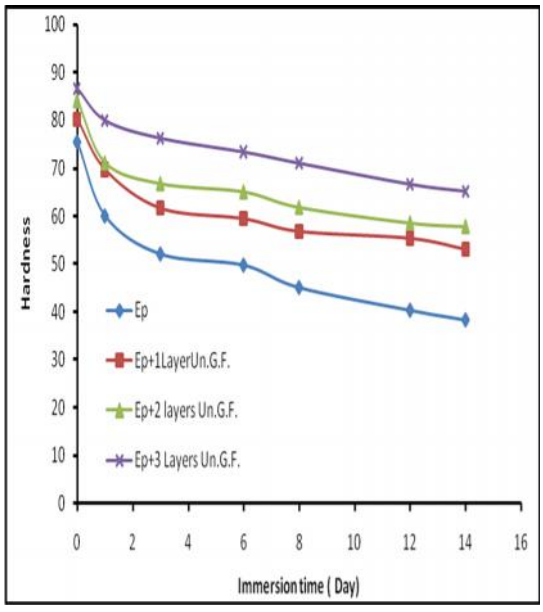

Fig. (2) : The relation between hardness and immersion time in water for samples reinforced with different layers of uniform glass fiber.

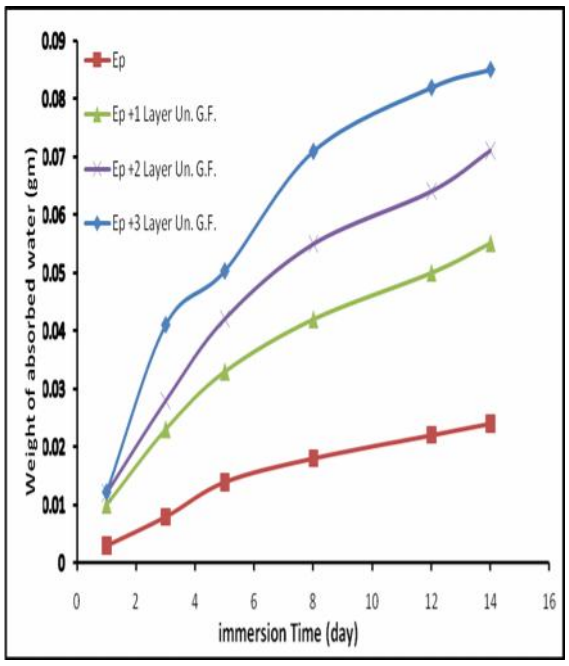

Fig. (4) : the relation between the weight of the absorbed water and the immersion time for samples reinforced by different layers of uniform glass fibers.

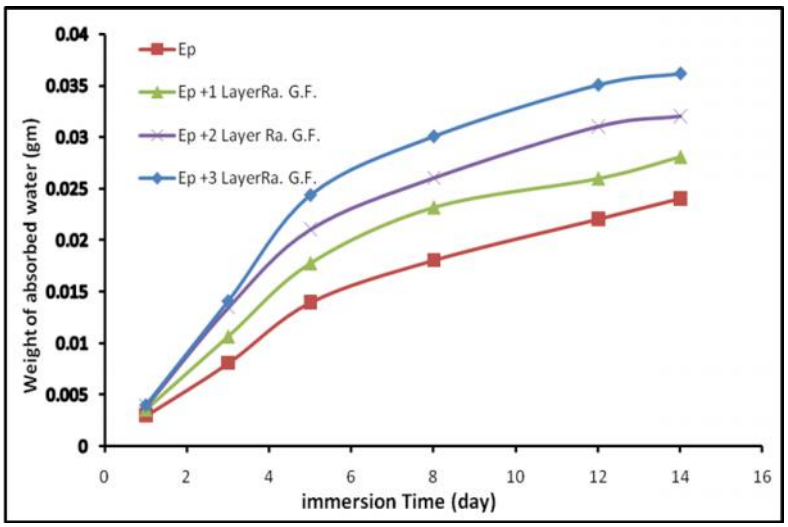

Fig. (5) : the relation between the weight of the absorbed water and the immersion time for samples reinforced by different layers number of random glass fibers.

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تاثير امتصاصية الماء على خاصية الصلادة للأيبوكسي المدعم بالألياف الزجاجية

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الخلاصة

يتضمن البحث دراسة تأثير امتصاصية الماء على خاصية الصلادة للأيبوكسي المدعم بالألياف الزجاجية . إن المادة المتراكبة تم تحضيرها من راتنج الأيبوكسي [EP-10] كمادة أساس و تمت تقويته و تسليحه بالألياف الزجاجية بنوعيها المتعامد (0 – 90o) و العشوائية و بكسر حجمي قدره 25% . تم قياس خاصية الصلادة لجميع النماذج قبل و بعد الغمر بالماء و بدرجة حرارة الغرفة و بينت نتائج الدراسة بأن قيم الصلادة تقل مع زيادة زمن الغمر بالماء ، و أن وزن الماء الممتص يزداد بزيادة أيام الغمر و خصوصا في الأسبوع الأول . إن كمية الماء الممتص تقل أو تزداد حسب نوع و عدد طبقات التقوية من ألياف الزجاج .