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STUDYING THE EFFECT OF VOLUME FRACTION VARIATION AND ENVIRONMENTAL IN CREEP BEHAVIOR OF POLYESTER RESIN COMPOSED WITH FIBER E-GLASS(MAT) AND CARBON BLACK POWDER PARTICLES

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ABSTRACT

This research presents the results obtained from investigation of creep behavior for polyester resin composited with different volume fractions of fiber E-glass(roving) and carbon black powder under 4-point flexure test at ambient and 60ºC. Flexure strength of W.R. composites show best values in comparison to particulate C.B. composites or to mixed W.R./C.B. composites.

The creep strain measured up to 103 h for three different stresses namely 15,30 and 45 MPa shows that W.R. composites endures least strain of all other specimens. The 60ºC temperature has little effect on the creep strain, at this temperature the creep strain increases by about 8% for the prepared specimens. Plot of creep modulus vs. time shows that the characteristic behavior is reciprocal of creep strain. Prior immersion in water to specimens for 30 days reveal that creep strain progressively increased for all prepared composites.

INTRODUCTION

The long-term behavior of Polymer Matrix Composites (PMC) is a critical issue for many modern engineering application such as aerospace, biomedical and civil engineering infrastructure. The primary concerns in long-term performance of (PMC) are in the screening for final material selection, and in obtaining critical engineering properties that extend over the projected life time of the structure.

Viscoelastic creep among the critical properties needed to assess long term performance of (PMC).

Flexural strength σ using three point flexural bend(for bending test) procedure(for bending test) is defined by(Settle,1997and ASTM D790-80,1979):

$$\sigma=\frac{3PL}{bd^2} \text{ --------------------- } (1)$$

Where

σ is stress in the outer fibers at midspan (P_a)

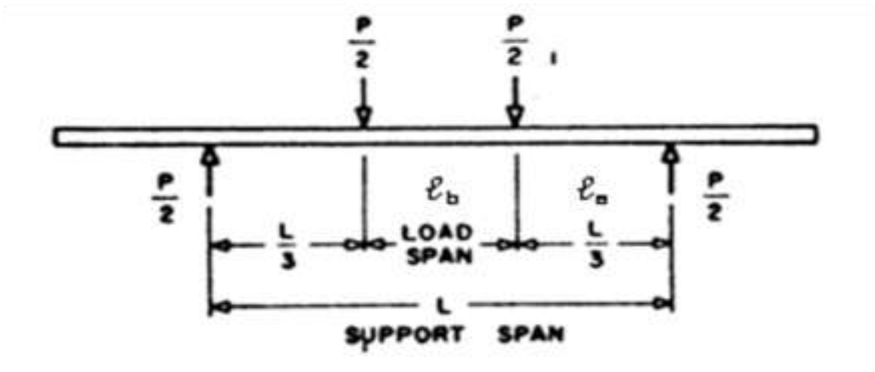
p is Load at a given point of the Load-deflection curve (kg)

L is Support span(m)

b is width of beam tested, of test specimen (m), and,

d is thickness of test specimen(m).

Creep in flexure test is based on the loading configuration shown in Fig(1). The test method is used for determining flexural strength and modulus.



Figure(1): Four point flexure loading (ASTM 790D-80, 1979)

The stress is defined as :

$\sigma = \frac{3Pl_a}{bd^2}$ --------------(2)

where

p is the load

ℓ_a is the right support span

b is the width of test specimen

d is the thickness test specimen

Strain is the loading parameter in the creep behavior and it is obtained by recording deformation in the test specimen under loading condition.

For 4-point loading assembly, the strain (Є) is defined as (Jain et.al,1997)

$Є= \frac{4df}{l_b^2} \times 100$ ------------(3)

Where d= specimen thickness

f= deformation

l_b= distance between loading noses .

The modulus can be defind by

$E= \frac{3Pl_a l_b^2}{4bh^3 f}$------------------- (4)

Where p is the load required,l_a andl_b are lengths of the right and left supporting spans respectively as shown in Figure (1),whereas b and d are the width and thickness of the sample, f is the value of the deformation.

MATERIALS AND METHODS

Polyester as matrix material was used in this study to prepare the polymer matrix composite. The rate of polymerization for this resin is too slow, and for practical purpose the catalyst [Methel Ethel Keton peroxide (MEKP) in a proportion of 0.5 for each 100g of the resin] and accelerator [(cobalt-napthenate catalyst) in a proportion of 0.1gm for each 100g of the resin with in a practical time period] have been used.

Accelerator added to the resin was recommended by polyester manufacturer to create a pre accelerated resin. This resin was supplied from Sabic Co. in Saudi Arabia.

Glass Fibers

The E- glass fibers used in this study to reinforce the polyester resin. The glass fibers have been used, was woven roving strand mat.

Carbon black powder

Carbon black powder has been used to prepare polymer composites either as particulate or filamentary combined with E-glass fiber.

Specimens preparation

Mould preparation

The mold made of glass in dimensions 39 X 30 X 0.4cm,cast all specimen. They were coated with paraffin wax for easier separation of composite.

After preparation of the resin with the desired volume fraction it was cast in the glass mould.

Load was put on the top of the glass layer to squeeze out air bubbles during curing.

Polymer composite preperation

Filamentary composite

The specimens were carried out by using woven roving. The reinforced fibers were cut into sheets with dimensions of (30 X 39)cm^2 and the polyester resin was then prepared via the previous mentioned way. Volume fraction of the additives and the matrix were evaluated by:

$$V_r + V_f + V_p + V_{anyadditive} ----=1 \quad (5)$$

Where V_r is volume fraction of the resin

V_f is volume fraction of fiber

V_p is volume fraction of particle

$V_{any\ additive}$ is volume fraction of any other additive

Specimens with different volume fraction of E-glass type are listed in table (1)

The resin was prepared in a volumetric beaker and is divided equally between the layers of glass fiber.

Hand lay-up method was used to prepare this type of composite by applying the amount of the resin into the mould and evenly distributed by using a brush and lying the dry fiber mat on the resin and carefully press on it by a brush to remove the air bubbles. Another amount of the resin was applied on top of the mat and also evenly distributed by a brush. This sequence was repeated until the desired volume fraction have been reached.

Table 1: Summary of composite reinforcement types and their volume fractions.

Specimen type	Volume fraction of fiber filler	Bearing load in creep test MPa
1- neat polyester resin(U.P.)	**0.00**	**15**
2- polyester + Woven Roving E-fiber glass(U.P.+ W.R. fiber E-glass)	**0.06**	
	0.12	**15 , 30**
	0.19	**30**
	0.25	**15 , 30 , 45**
3- polyestar reinforced by carbon black particles(U.P.+C.B. particles)	**0.06**	
	0.12	
	0.19	
4- polyester reinforced by carbon black particles and Woven roving fiber E-glass (U.P.+W.R.+C.B.)	**total vf. of reinforcement 0.12 fiber 0.6, C.B 0.6**	
	total v.f of reinforcement 0.24 fiber 0.125 , C.B. 0.125	**15, 30**

Particulate composites

When incorporation by carbon black particles the polyester and filler were prepared according to the desired volume fraction and molded as previously mentioned.

The filler powder was weighed according to the desired volume fraction evaluated from eq.(5) and was gradually added to the resin with through mixing until a homogeneous mixture have been obtained. The prepared composite was cast into the mould and left out for 24 hours to complete setting. It finally was placed into a furnace at 60^{0}C for four hours post curing.

Filamentary / Particulate composites

1- The woven roving E-glass fibers were cut according to the desired molding area.

2- The carbon black powder was weighed according to the desired volume fraction evaluated from eq.(5), used for preparing, and it was mixed with the prepared resin as mentioned in the previous section.

3- This type of specimen was also prepared by hand lay up method as previously mentioned .

4-The resin was mixed with the filler powder (carbon black) and then evenly distributed on the layers of the glass fibers.

5- Prepared specimen were left out at laboratory temperature for 24 hour for setting.

6-For post curing the specimens were placed in an oven for four hours at 60°C.

Specimens dimensions

Molded sheet had been cut into strips of length 39cm and width 2cm for creep test and to strips of 10cm in length and 2cm in width for bending test via an electric saw blade.

The dimensions of the specimens were choosen according to the ASTM (D790) standard for creep and bending tests(ASTM D790-80,1979).

Bending test

Mechanical testing was performed using a computer controlled tensile testing machine model (HK 50) from Tenis Olsin, UK, employing 3-point bending test.

Crosshead speed and span were fixed at 1mm/min and 50mm respectively. Dimensions of specimens were prepared according to (ASTM D790-80,1979).

Creep test

For the purpose of this study, the creep testing device was designed and manufactured according to four point loading test in flexure. [3].

Figure (2) shows schematic loading assembly. The test strip was laid first on two support noses; and the two loading noses assembly was then fixed on the strip. Each nose had an equal distance from the adjacent support point. The distance between the loading noses was about one third of the support span.

Both of the loading and support noses have cylindrical surfaces to avoid excessive indentation or failure due to stress concentration directly under the loading nose or noses (ASTM D790-80,1979).

The loading weights were supported on the pan of the loading assembly while the specimen was being installed on the support. The loading pan was then slowly released so that the load was applied to the specimen very slowly.

After loading the specimen, deflection was recorded at selected time interval. by dial gauge which has been positioned at the center of span. Deformation due to creep was recorded for 45 days under each particular load chosen.

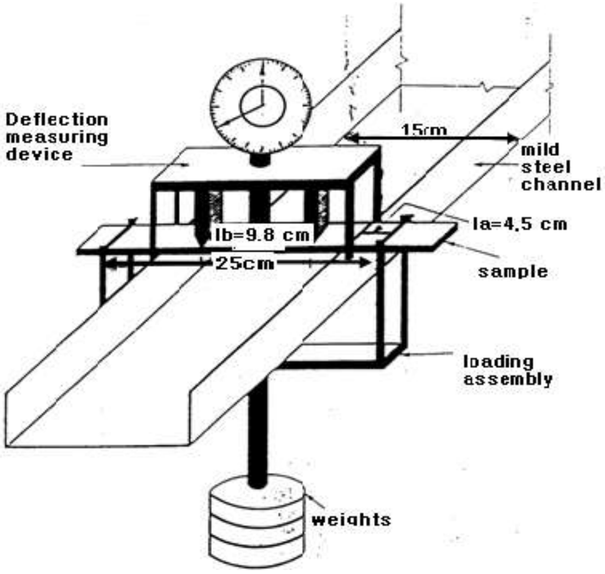


Fig.(2,) Four point loading assembly showing the deflection measuring device(Jain et.al,1979).

Heat creep test

Creep test assembly was equipped with heat facility to test creeping of the specimens at elevated constant temperature of 60°C measured by thermometer near the specimen. Arrangement of the heat facility is shown in Fig (3). Part (a) is the creep testing device, part (b) is a variable height base to hold the heat source, part (c) is the heat source and the blower. Deflection data were taken for eight hours at selected time intervals, from which creep behavior could be drawn in comparison with room temperature creep test.

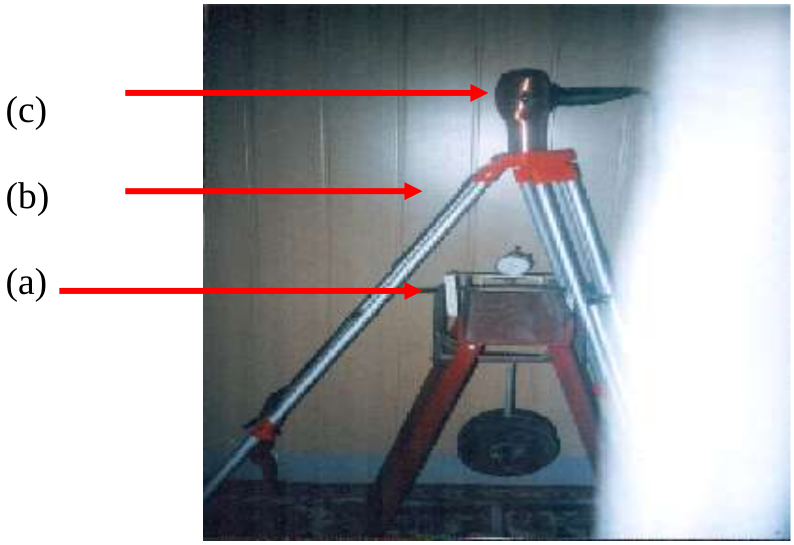


Fig (3) *In-situe* heat creep test

Water immersion measurements

Selected specimens were immersed in water at room temperature for a period of one month. Weights of the specimens before and after immersion were measured by a digital balance with 0.1 mg in sensitivity.

RESULTS AND DISCUSSION

Bending test:

Prior to creep test the specimens were tested by three point bending test to determine the flexural strength in order to assign the range of stresses to be subjected during creep test.

From the load-deflection curve, the flexural strength was calculated using equation (1). The results are shown in Table (2)

Table (2) Flexural strength and Strain(%) values(3-point bending test)

Specimen description		Vf	Flextural strength (MPa)	Strain (%)
Resin	Filler			
U.P.	---	---	133	0.7
	W.R.	0.06	125	3.3
	W.R.	0.12	127	3.5

W.R.	0.19	138	3.5
W.R.	0.25	139	3.4
C.B.	0.06	50	0.6
C.B.	0.12	43	0.9
C.B.	0.19	32	1.0
W.R.+C.B.	0.125	86	3.5
W.R.+C.B.	0.24	99	3.4

Error in $\sigma\beta \pm$ 5MPa
$Є \pm$ 0.2%

We notice from table (2) that unsaturated polyester reinforced with woven roving fiber E-glass(U.P.+W.R. fiber E-glass, vf.=0.19,0.25) has the largest flexural strength because if a long fiber reinforced composite is subject to mechanical loading, the role of fibers is to bear the applied load ,whereas the matrix binds the fibers together and ensures that the load transfer to and distributed between the fibers(Mishnaevisky,2007),follows by neat unsaturated polyester(U.P.) follows by unsaturated polyester reinforced with woven roving fiber E-glass(U.P.+ W.R. fiber E-glass, vf. = 0.06, 0.12) ,because a large bending stiffness is obtained by placing the stiff material in the faces far from the neutral axis. The faces, which can be of different thickness on each side, take up most of the normal stresses in the structure (Good hew et.al,2004), follows by unsaturated polyester reinforced with woven roving fiber E-glass and carbon black particles(U.P.+W.R. + C.B.), in these specimens, flexural strength increased with increasing the volume fractions of the additives, follows by unsaturated polyester reinforced with carbon black particles(U.P. + C.B.), because particle cleavage, if brittle particle are placed in a ductile but strong and tough matrix, particle cleavage is the main damage mode in the initial stages of deformation ,and debonding on the particle-matrix interface. If the bond strength of the interface is low compared with the failure strengths of both the particles and the matrix, the initial damage may occur at the interfaces. Often the stress concentration on broken particles causes the initiation of the void growth in the matrix and/or interface debonding, and the toughening mechanisms in particle reinforced composites is(crack, branching, deflection)(Mishnaevisky,2007)while in U.P.+C.B. specimens, the flexural strength decreased with increasing the volume fraction of the additives.

Creep behavior at ambient temperature.

Dry specimens

The loading weights required for applying a particular stress were calculated by using relation (2).

The deformation was obtained from the creep test, whereas eq.(3) was used to measure the strain. The variation of strain with time for specimen tested are shown in Figures (4) to (9) under 15,30,45 MPa stress.

Table (3) illustrate specimen and strain at the beginning of the test, while the Figures (4) to (9) illustrate the creep behavior at ambient temperature .

When a constant load is applied (except for a short initial duration where the strain may increase quite rapidly) to a viscoelastic material, the strain increases steadily. This increase of strain is creep (Plyush,1998) .

The strength bonding in a solid does not vary appreciably with temperature (Good hew et.al,2004). However in a polymer it becomes easier for parts of neighboring chains to slip to new positions as the temperature rises. This will allow the chain to slide over each other under an applied stress. The longer time the sample is left under the more it will deform .This gives rise to creep in polymers (Good hew et.al,2004).

Table(3) Results of creep test for unsaturated polyester composites under different load at room temperature.

samples	Vf	15 MPa			30MPa			45MPa		
		Є$_0$	**Є**	**Δ Є**	**Є$_0$**	**Є**	**Δ Є**	**Є$_0$**	**Є**	**Δ Є**
neat		0.17	0.181	0.011						
UP+W.R.	0.12	0.131	0.142	0.012	0.234	0.246	0.012			
	0.19				0.21	0.219	0.01			
	0.24	0.106	0.111	0.005	0.142	0.151	0.009	0.268	0.277	0.009
UP+C.B.	0.06				0.258	0.314	0.056			
UP+W.R.+C.B.	0.24	0.152	0.172	0.021	0.375	0.39	0.024			

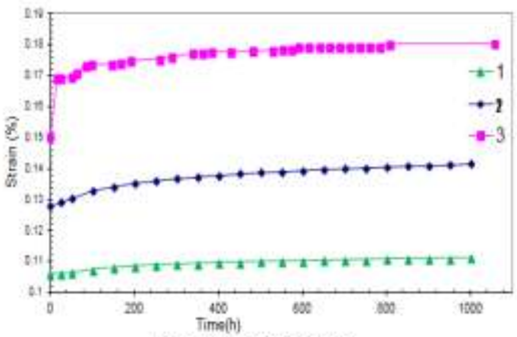


Fig (4) Creep behavior for(1) UP+W.R.(vr=0.24),(2)UP+W.R.(vr=0.12),(3) neat UP,loaded under 15 MPa stress

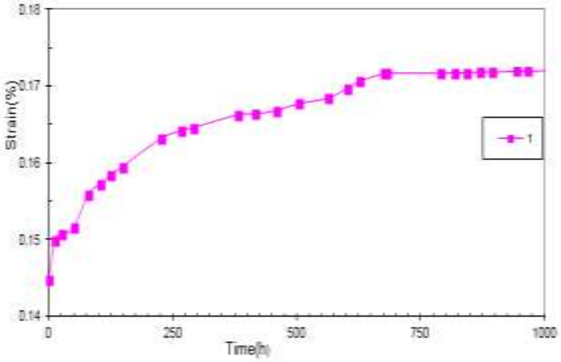
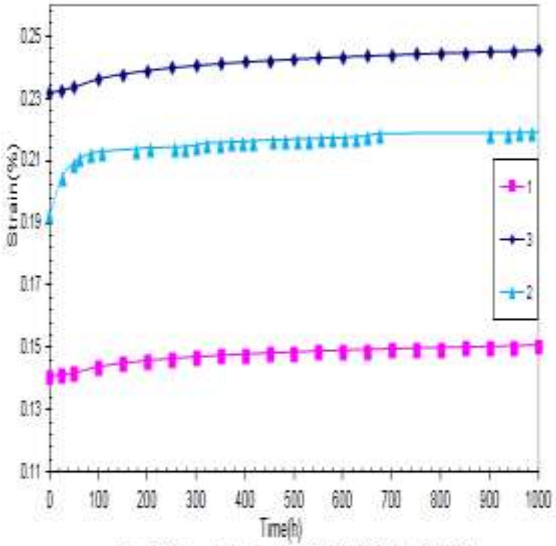


Fig.(5) Creep behavior for (1)UP+W.R.(vr=0.12)+C.B.(vr=0.12),loaded unde 15 MPa stress



Fig(6) Creep behaviour for (1) UP+W.R.(vr=0.24),(2) UP+W.R.(vr=0.19),(3) UP+W.R.(vr=0.12),loaded under 30 MPa

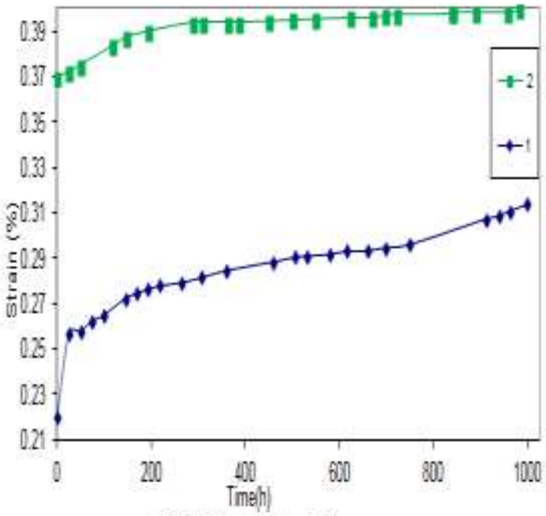
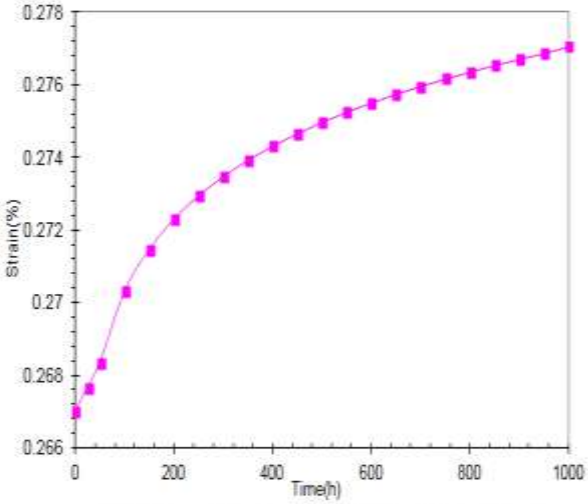


Fig.(7): Creep behavior for (1)PE+C.B.(vr=0.06),(2)UP+W.R.(vr=0.12)+C.B.(vr=0.12) Loaded under 30 MPa



Fig(8): Creep behavior for UP+W.R.(vr=0.24)loaded under 45 MPa

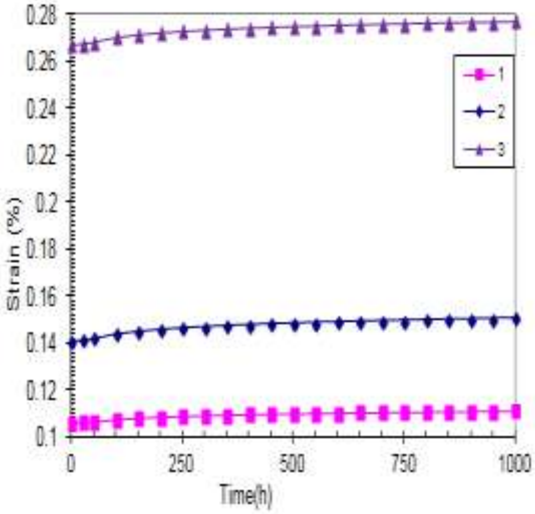


Fig.(9) Creep behavior for UP+W.R.(vr=0.24),loaded under(1)15 MPa,(2) 30 MPa,(3)45 MPa stresses

From Figures(4) to (9),and table (3), ,under a pressure of 15 Mpa in U.P.+W.R.(vf=0.12) specimen, increasing in strain was 0.011 followed by neat polyester specimen because large bending stiffness is obtained by placing the stiff material in the faces far from the neutral axis. The faces, which can be of different thickness on each side, take up most of the normal stresses in the structure(Jacobs and Jones,2004), in U.P.+W.R.(vf=0.24) specimen, increasing in strain was 0.005 because if a long fiber reinforced composite is subject to mechanical loading, the role of fibers is to bear the applied load ,whereas the matrix binds the fibers together and ensures the load transfer to the fibers and distribution between them (Mishnaevsky,2007). Some factors which affect creep behavior are:

a. Effect of volume fraction of fibers / particles

From table (3),we notice that in all specimens which have containing fiber E-glass in their structure ,creep decreased by increasing volume fraction of the fiber. This can be explained by the higher concentration of fibers (at any orientation), the lower will be the creep rate. This is because there is less of resin available to deform, also glass fiber do not creep in a significant amount at room temperature. Creep is a function of the applied stress, fiber orientation, fiber volume fraction, and ductility of the resin (Raghavan and Meshii,1997), whereas in specimens containing particles only as carbon black, creep increased by increasing the volume fraction of the particles.

b. Effect of increasing stress on creep behavior

From table (3) we notice that in all specimens subjected to creep test , the creep increases when the stress increased because of increasing the mechanical stress has several effects at the molecular level. Diffusion of gas and liquids into the polymer matrix is enhanced and some population of chemical bond in the polymer chain will be loaded to higher level, thereby reduction the energy needed to rupture the bond. In turn, at the macroscopic level the time to achieve a characteristic damage state will be reduced (Gates,2003), (Raghavan and Meshii,1997),(Broughton et.ah,2002).

For polyester specimen reinforced by woven roving fiber E-glass when loaded, stress concentration areas exist at fiber ends. Creep damage might be initiated at these areas and then it developed with time goes on (Gates,2003),(Lu and Yie,1988).

Water immersed specimens

Table (4) illustrate the weight percentage of water absorption for neat polyester and polyester composite specimens immersed in water at room temperature for 30 days before subjected to creep test.

Table (4) Water absorption by specimens for 30 days period

Composites polyester specimen	Volume fraction	Weight percentage of water absorption (%)
Neat		**0.693**
Polyester + woven roving	**0.06**	**0.653**
Polyester + woven roving	**0.12**	**0.544**
Polyester + woven roving	**0.19**	**0.463**

Polyester + woven roving	**0.25**	**0.437**
Polyester + carbon black particles	**0.06**	**0.704**
Polyester + carbon black particles	**0.12**	**0.722**
Polyester + carbon black particles	**0.19**	**0.735**
Polyester + woven roving + carbon black particles	**0.125**	**0.665**
Polyester + woven roving + carbon black particles	**0.24**	**0.587**

From this table we notice that the weight percentage value of water absorption is small in the specimens. This is because of immersing them in water for a small period of time as well as because of a small volume fraction of the additives. E-glasses belong to the group of aluminosilicates and are characterized by their relatively high proportion of aluminum oxide content(Al_2O_3).Furthermore this type of glass has a low sodium(Na) fraction, which increases resistance to water attack (Riebel,2006).This is in fact was the reason for low water absorption in specimens reinforced with fiber E-glass.

Due to their large specific surface areas, carbon blacks have a remarkable adsorption capacity for water, solvents, binders, and polymers depending on their surface chemistry (Leendertse and Veen,2002).Table(5),illustrate results of creep test for water immersed specimens at room temperature and Figures (10) to(14) illustrate creep behavior for water immersion specimens.

Table(5) Results of creep test for water immersion at room temperature, ΔЄ, represents to the increase in strain for all the specimens, the minus sign denoted to the failure occurred.

specimens	Volume fraction	15 MPa (water)		ΔЄ= ΔЄwater- Δ Є dry	30Mpa (water)		ΔЄ= ΔЄwater- Δ Є dry
		ϵ_0	ϵ		ϵ_0	ϵ	
Neat UP		0.197	0.202	-0.004			
UP+W.R.	0.12				0.245	0.23	-0.025
	0.19				0.13	0.117	-0.021
	0.24	0.042	0.051	0.005	0.14	0.138	0.007
UP+C.B.+W.R.	0.24	0.173	0.181	-0.008	0.327	0.250	-0.097

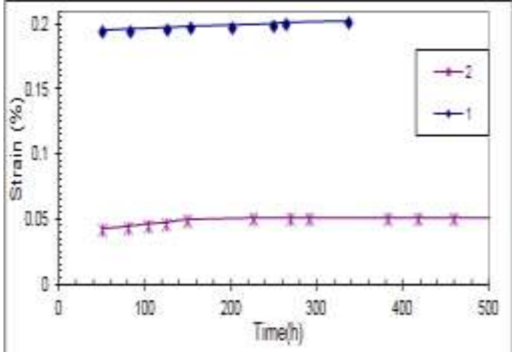


Fig.(10):Creep behavior for (1) neat UP(2)UP+W.R.(vf=0.24),immersed in water for 30 days before subjected to creep test under 15 MPa stress

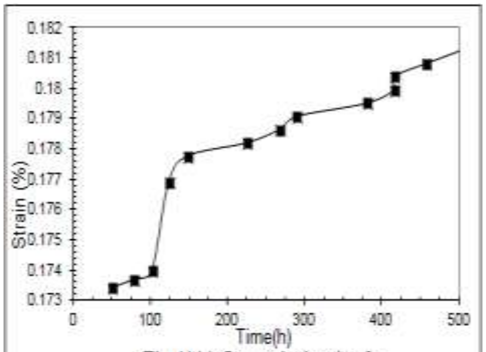


Fig.(11) Creep behavior for UP+W.R.(vf=0.12)+C.B.(vf=0.12), immersed in water for 30 days before subjected to creep test under 15 MPa stress

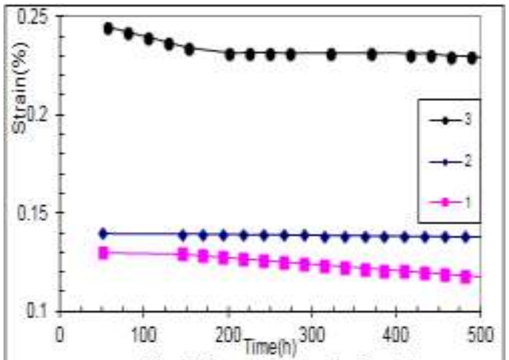


Fig.(12) creep behavior for,(1) UP+W.R.(vf=0.19),(2)UP+W.R.(vf=0.24),(3)UP+W.R.(vf=0.12),immersed in water for 30 days before subjected to creep test under 30 MPa stress

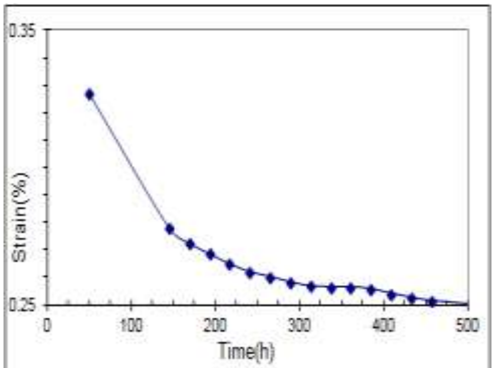


Fig.(13) Creep behavior for UP+W.R.(vf=0.12)+C.B.(vf=0.12), immersed in water for 30 days,before subjected to creep test under 30 MPa stress

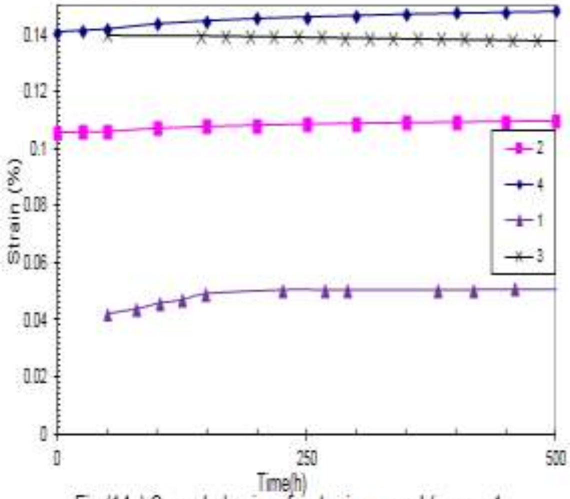


Fig.(14) Creep behavior of water immersed (curves 1 and 3) and dry (curves 3 and 4) for UP+W.R.(vf=0.24) at 15 and 30 MPa stresses respectively.

From table(5) we notice that under a 15 MPa stress the increase in strain was in U.P.+W.R.(vf=0.12)+ C.B.(vf=0.12)was (0.0084) since carbon black raises the viscosity (Mason,1960). For neat polyester the largest increase in strain was(0.0041), Barrie et al. included the possibility of clustering of water molecules at high activities. Also the ability of water molecules to form hydrogen bonds with other molecules and /or polar groups in the polymer gives rise to plasticization. It further affects the behavior of the sorption and diffusion of water in the polymer and the formation of polymer-water intermolecular bonds and the rupture of polymer-polymer intra-molecular hydrogen bonds, which stiffen the polymer network, strongly depress the glass transition temperature (Feng,2001). Also the polymer chains had disrupted and the effective cross-link density decreased, resulting in reduced mechanical properties(Dohnalek,2006).The increases in strain in U.P.+W.R.(vf=0.24)specimen was 0.005 because although FRP composites are in general environmentally stable and has resistant to many chemicals, moisture absorption is very detrimental to their mechanical properties. In FRP composite water acts as a resin plasticizer, softening the material and thus changing its mechanical properties. The water absorption also decreases glass transition temperature of the composite (Dohnalek, 2006).

For glass fibers, degradation is initiated by moisture extracting ions from the fiber thereby altering its structure. Volume change or swelling is another possible effect of moisture ingress. Similar to thermal effect, it can cause the stress between fiber and resin resulting micro cracks. Swelling can also lead to the loss of bond between the fiber and resin. However, the extent of possible delamination due to the loss of bond is largely dependent on the nature of the sizing or coupling agent (Schutte,1994) . In FRPs the reinforcement will moderated the change in mechanical properties .However, there are other possibilities, such as glass fiber-resin debonding caused by water absorption from aqueous liquids. This can reduce translucency load transfer between fibers which is also less effective (Halliwell,2002). Once the ingressed moisture begins to react chemically with the glass, accelerated degradation of a composite is also caused by the leaching of alkaline components from the glass, in turn increasing the concentration of OH^- ions in the interphase(Riebel,2006).

Creep behavior at high temperature

The creep properties of a polymer are very temperature dependent. At temperatures below the glass transition temperatures, the polymer is rigid possessing a high modulus. Since segmental movement of the chains cannot occur below this temperature, a very little creep will take place even after long periods of time. As the temperature is raised, not only does the elongation increase, but the rate of creep also increases since segmental motion can take place (Van,1976).Increasing the temperature accelerates all thermally activated rate processes and will also reduce the activation energy of chemical bond rupture in the polymer. Elevate temperature (sub. Tg) will also increase the free volume in the polymer, hence decreasing the time needed to age to thermodynamic equilibrium. Increased temperature is usually associated with decreases in both strength and stiffness in PMC'S and will lead to increase ductility and strain to failure (Gates,2003). Table(6) shows the results of creep test at 60˚C,where the specimens have been arranged from the largest increase in strain to the lowest one. The minus sign denotes to the failure occurred. Figures (15 ,16) illustrate creep behavior for specimens tested at 60˚C .

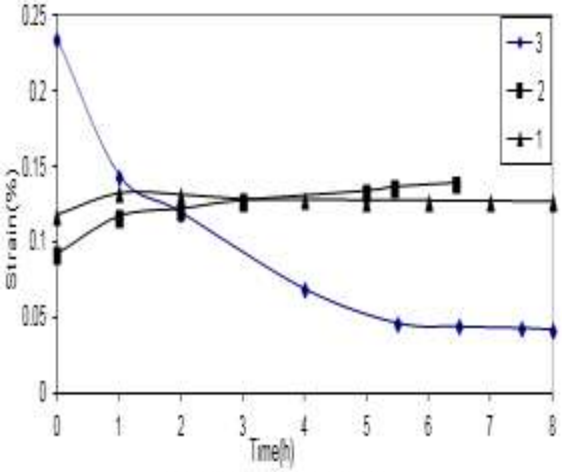


Fig.(15) Creep behavior,for(1) UP+W.R.(vf=0.24),(2)UP+W.R.(vf=0.12),(3) neat UP,at 60 C temperature,loaded under 15 MPa

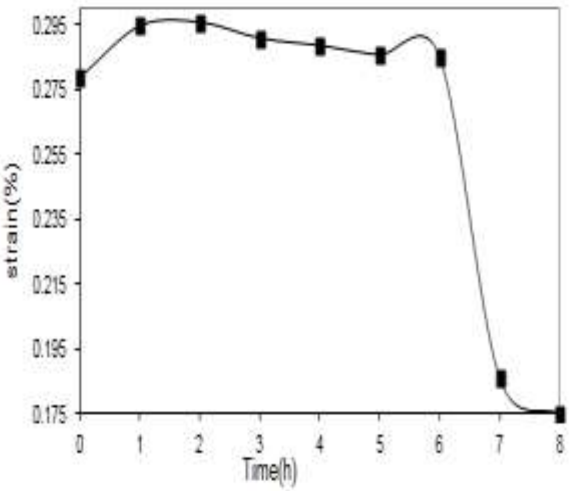


Fig.(16):Creep behavior,for UP+W.R.(vf=0.12)+C.B.(vf=0.12),at 60 C temperature,loaded under 15 MPa

Table (6) Results of creep test at 60 ˚C.

specimens	Volume fraction	Є$_{o}$	Є	ΔЄ with heat – ΔЄ without
Neat UP		0.235	0.043	-0.198
UP+W.R.+C.B.	0.24	0.279	0.175	-0.106
UP+W.R.	0.12	0.093	0.14	0.047
UP+W.R.	0.24	0.054	0.064	*0.009*

The increase in strain in UP+W.R.(vf=0.12)+C.B.(vf=0.12)specimen was(0.106) because C.B. particles raise the viscosity [15].

Creep Modulus

The modulus could be obtained by using Eq. (4). Figures from (17) to (28) illustrate the results of creep modulus for specimens at ambient temperature.

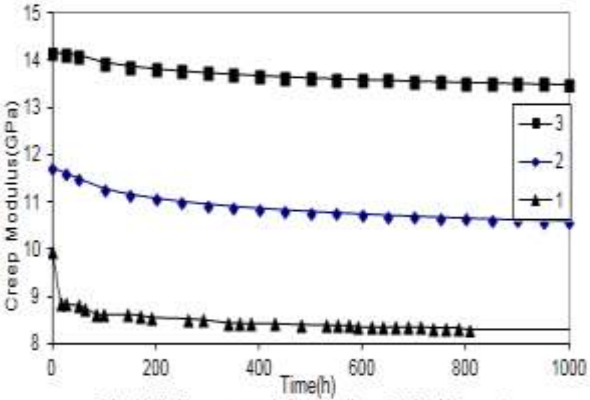


Fig.(17): Creep modulus,vs.time(h),for(1) neat UP,(2) UP+W.R.(vf=0.12),(3) UP+W.R.(vf=0.24),loaded under 15 MPa

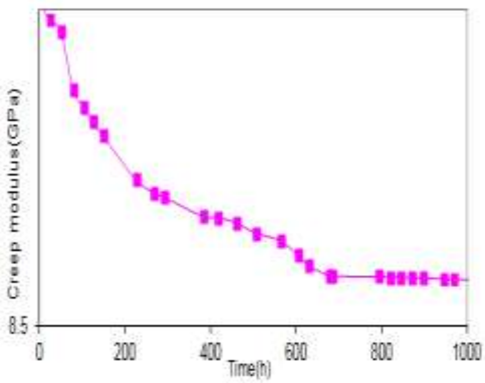
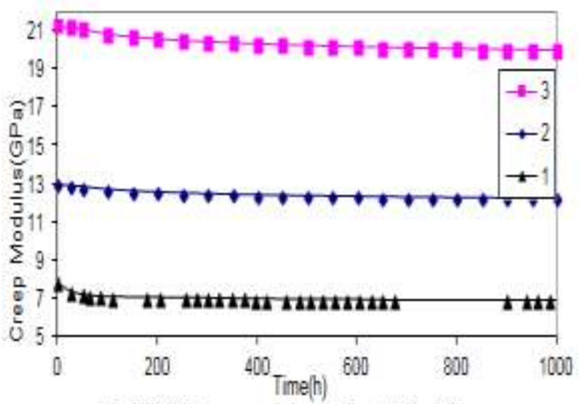


Fig.(18): Creep modulus,vs.time(h),for UP+W.R.(vf=0.12)+C.B.(vf=0.12),loaded under 15 MPa



Fig(19): Creep modulus,vs.time(h),for(1) UP+W.R.(vf=0.19),(2) UP+W.R.(vf=0.12),(3) UP+W.R.(vf=0.24),loaded under 30 MPa

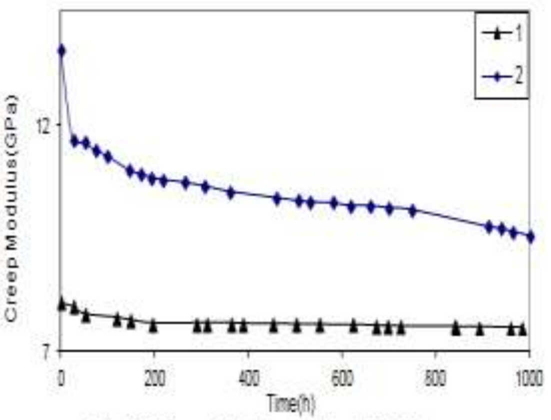


Fig.(20) :Creep Modulus,vs.time(h),for(1) UP+W.R.(vf=0.12)+C.B.(vf=0.12),(2) UP+C.B.(vf=0.12),loaded under30 MPa

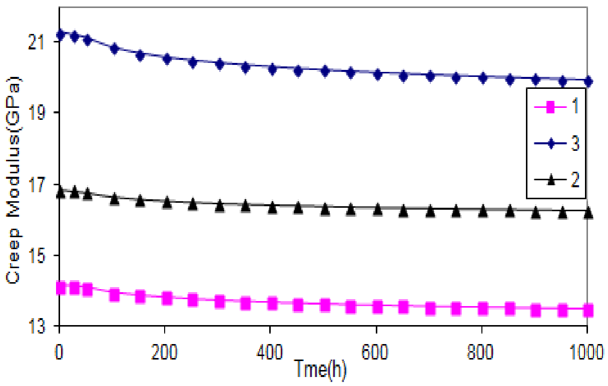


Fig.(21): Creep Modulus,vs.time(h),for UP+W.R.(vf=0.24),loaded under (1) 15 MPa,(2) 45 MPa,(3) 30 MPa stresses

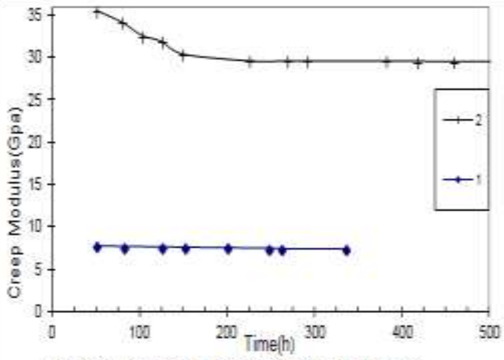


Fig.(22) creep modulus(GPa),vs.time(h),for (1) neat UP,(2)UP+W.R.(vf0.24),immersed in water for 30 days before subjected to creep test under 15 MPa stress

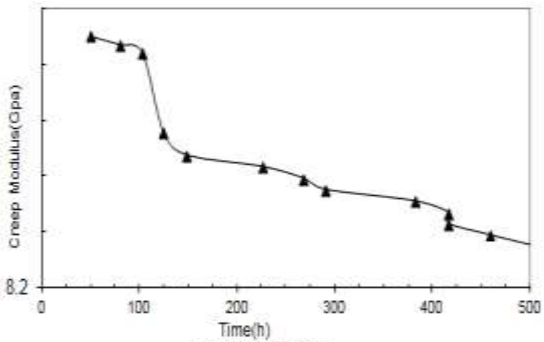


Fig.(23) Creep Modulus(GPa),vs.time(h),forUP+C.B.(vf=0.12)+ W.R.(vf=0.12) ,immersed in water for 30 days before subjected to creep test under 15 MPa stress

From all the figures we notice that as the strain is increased , creep modulus gets decreased .

If the weight (stress) is left on over a period of time, the amount of bending or elongation continue to increase, and the value for the creep modulus will decrease with time. This decreasing in modulus is a faction of time and even temperature (Feng,2001).

The effect of creep is a reduction of the Young's modulus. This reduction of Young's modulus is denoted as the creep modulus.

Conclusion

●For all specimens with the same volume fraction of the additives ,the creep was largest in unsaturated polyester incorporated with carbon black particles, followed by

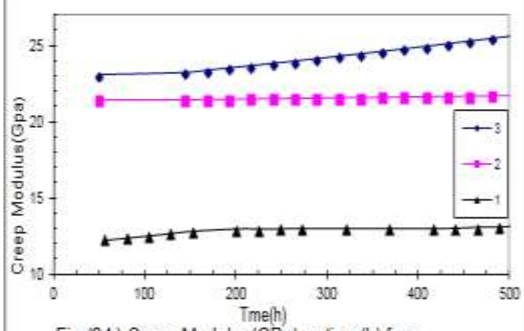


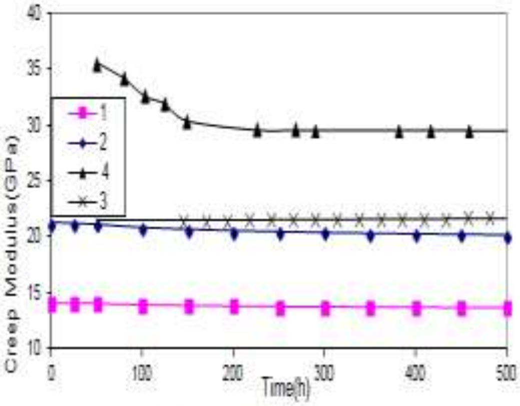
Fig.(24) Creep Modulus(GPa).vs.time(h).for (1)UP+W.R.(vf=0.12),(2) UP+W.R.(vf=0.24),(3) UP+W.R.(vf=0.19),immersed in water for 30 days before subjected to creep test under 30 MPa stress

unsaturated polyester enforced by fiber E glass and carbon black particles(with same volume fraction for each one) , followed by unsaturated polyester enforced by fiber E-glass.

●For unsaturated polyester incorporated with carbon black particles, the creep was larger, and increased as particle volume fraction increases.

●lower creep has been obtained by placing the stiff material like woven roving fiber E-glass in the faces far from the neutral axis.

● Creep increased by increasing stress.



Fig(26) creep modulus.vs.time(h) of water immersed (curves 4,3),and dry (curves 1 and 2) for UP+W.R.(vr=0.24),at 15 and 30 MPa stresses respectively

● Creep increased in all specimens immersed in water for 30 days before subjected to creep test.

● Creep increased for all specimens heated to 60˚C under creep test.

●In all specimens reinforced by fiber E-glass, creep decreased by increasing the volume fraction, whereas for specimens incorporated with carbon black particles ,creep increased by increasing the volume fraction .

●From studying creep modulus, as strain increased creep modulus decreased.

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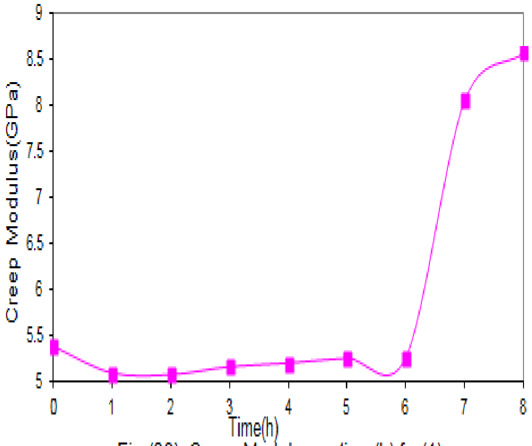

Fig.(28) :Creep Modulus.vs.time(h).for(1) UP+W.R.(vr=0.12)+C.B.(vr=0.12),at 60 C temperature,loaded under 15 MPa

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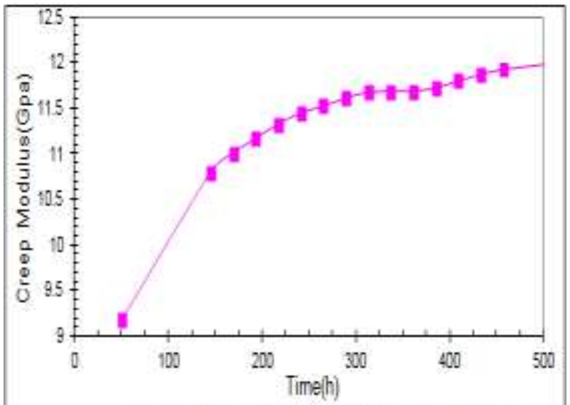

Fig.(25): Creep Modulus(GPa),vs.time(h),for (1)UP+C.B.(vr=0.12)+W.R.(vr=0.12),immersed in water for 30 days before subjected to creep test under 30 MPa stress

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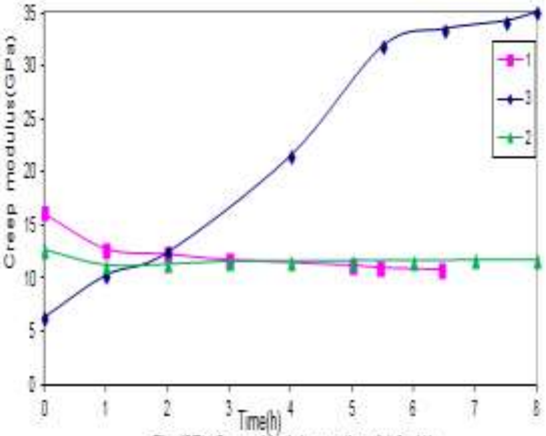

Fig.(27): Creep Modulus vs.time(h),for(1) UP+W.R.(vr=0.12),(2)UP+W.R.(vr=0.24),(3) neat UP,at 60 C temperature,loaded under 15 MPa

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دراسة تأثير اختلاف الحجم الجزئي وسلوك الزحف البيئية لراتنجات البوليستر المتراكبة مع اليافE الزجاجية (حصيرة) وجسيمات الكربون الاسود

الخلاصة

هذا البحث يقدم نتائج تم الحصول عليها من التحقيق في سلوك الزحف لراتنج البولي استر المتراكب مع كسور حجميه مختلفه من الالياف الزجاجيه (مجدوله وحصيره) ، ومسحوق اسود الكاربون) وتحت اختبار انحناء النقاط الاربعه عند درجة حرارة الغرفة و 60°م . اظهرت النتائج قوة الانحناء لمتراكبات WR بقيم احسن بالمقارنه مع متراكبات C.Bالدقائقيه او متراكبات W.R. /C.B. المختلطه .

بين انفعال الزحف المحسوب لمدة 10^3ساعه لثلاثة اجهادات مختلفه اي15، 30، 45 ميجا باسكال بان متراكبات WRتتحمل اقل انفعال بالنسبة لجميع العينات الاخرى.ان درجة حرارة 60°م له تاثير قليل على انفعال الزحف ويزيده بحوالي 8% للعينات المحضره .

أظهر معامل الزحف ازاء الزمن خصائص السلوك العكسيةلانفعال الزحف.

بين الغمر المسبق في الماء للعينات لمدة 30 يوما بان انفعال الزحف اخذ في الزياده لجميع العينات المحضره.

لێکۆڵینەوەی کاریگەری گۆڕانی ڕێژەی قەبارەیی و ناوەندی لەسەر ڕەفتاری خزان بۆ پێك هاتەی ڕێزینی پۆلیئەستەری تێکەڵ کراو لەگەڵ ڕێژەی قەبارەیی "ڕیشاڵی شوشەیی E " (چنراو) و تۆزی کاربۆنی ڕەش

پوختە

ئەم توێژینەوەیە ئەنجامەکانی بەدەست هاتوو لە لێکۆڵینەوە لەسەر ڕەفتاری خزان بۆ پێك هاتەی ڕێزینی پۆلیئەستەری تێکەڵ کراو لەگەڵ ڕێژەی قەبارەیی "ڕیشاڵی E شوشەیی " (چنراو) و تۆزی کاربۆنی ڕەش لە ژێر چوار خاڵی چەماوە ی تاقی کراو لە ناوەندی و (60) پلەی سانتی گرات پیشان دەدات .

توندی چەمانەوەی پێك هاتەی (W.R) باشترینە بە بەراورد لەگەڵ پێك هاتە تەنۆلکەیی یەکان (C.B.) یان تێکەڵەی پێك هاتەی (W.R./C.B.). جێ فشاری خزان بۆ هەزار کاژێر پێوراوە لێرەدا بۆ سێ فشاری جیاوازی (15) ،(30) ،(45) میگا پاسکاڵ پیشان دراوە کە پێکهاتەی (W.R) بەرگەی زیاتری جێ فشار دەگرێت .

لە (60) پلەی سەنتی گرەیت دا پلەی گەرمی کاریگەری یەکی لەسەر جێ فشاری خزان هەیە لەم پلەی گەرمی یەدا جێ فشار بە ڕێژەی ٪8 بۆ ئەو نموونانەی ئامادەکراون بەرز دەبێتەوە .

گرافی هاوکۆلکەی خزان بەپێ ی کات ،پێچەوانە لەگەڵ جێ فشاری خزان دا دەگۆڕێت لە پێش دا نوقم بوون بۆماوەی (30) ڕۆژ لە ئاودا دەری خست جێ فشاری خزان بەشێوەی زیادبوون بۆ هەموو نموونە ئامادەکراوەکان بەرزدەبێتەوە