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ENVIRONMENTAL WEATHERING OF FIBRE-REINFORCED POLYMER COMPOSITES

[1]Edwin Ikezue, [2]Josephine Ikezue and [3]Chidozie Udechukwu

[1]Department of Chemical Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria
[2]Department of Business Administration and Management, Federal School of Statistics, Enugu, Nigeria
[3]Department of Statistics, Federal School of Statistics Enugu, Nigeria
Email:eddikezue@yahoo.com[1], onyeka123439@yahoo.com[2], Udeanthony5@gmail.com[3]

Abstract

One major hindrance to the acceptance of polymer composites in engineering applications is the susceptibility of the polymer matrix to environmental weathering activities due to prolonged exposure. The polymer matrix is prone to degradation initiated by Ultraviolet radiation, moisture or water absorption, temperature and high pH environments. The paper highlights the characteristic chemical and physical changes in polymeric matrix resins following prolonged exposure to these environments. The main objective is to identify factors that contribute to matrix resin degradation under environmental and mechanical stresses. Resin systems considered in this study include vinylester, unsaturated polyester and epoxy resin. These are the polymer matrices employed in most industrial and construction applications. Neat polymer resins were exposed to moisture/water and high temperature environments and the susceptibility or responses to the changes were evaluated through gravimetric and differential scanning calorimetry (DSC). Scanning election microscopes (SEM) were also used to detect changes in the morphology of polymer composites surface following exposure to ultraviolet) UV) radiation.

Keywords: *epoxy- resin, polyester, polymer, ultraviolet-radiation, vinylester*

INTRODUCTION

With the continued deterioration of the world's infrastructure it has become increasingly urgent to determine the feasibility of using high performance polymer composite materials in fabricating new structures as well as rehabilitating existing ones. Anders (2001) has suggested the use of high performance materials and systems in construction due to substantial cost savings as a result of lower mass of materials, reduced maintenance and longer lifetimes. The advantages of fibre-reinforced polymer composites over the traditional building materials such steel and concrete have been recognized and they include high strength/weight ratio, excellent corrosion and chemical resistance, transparency to electromagnetic radiation and resistance to fatigue. The polymer matrix in a fibre reinforced composite binds and orients reinforcing fibre to carry the intended loads, protects them from handling and environment damage and provides all of the interlaminar shear strength of the composite (Nanni, 2004). However the matrix is often considered the weak link in a fibre reinforced composite system, since it may undergo physical damage and chemical degradation during environmental exposure and stress application. Polymer composites in outdoor applications are susceptible to photo-initiated oxidation leading to surface thermal degradation (Anders, 2006) and are also known to be sensitive to moisture-induced damage (Bledzki, Mamun & Farouk, 2007).

Polymer composites are also tauted for use as potential replacement for steel reinforcing bars in concrete, a highly alkaline environment as well as incorporation into offshore and marine structures, (Hayes & Gammon, 2010). At the present time little studies have been conducted on the effect of water/moisture absorption and thermal degradation on vinylester, polyester and epoxy polymer matrices.

The objective of the paper is to highlight studies on the chemical and mechanical changes in polymer composites following exposure to high temperature and water/moisture environments.

EXPERIMENTAL

Materials

Representative commercial epoxy, vinylester and polyester resins were selected for this research study. The materials are thermosetting systems which are suitable for fabricating fibre reinforced composites through handlay up process. Other materials include okro (hibiscus esculentus) fibre, Abari (Uremia lobata) fibre and banana (musa acuminata) fibre which were chopped into strands of 10 mm, 30 mm, 50 mm each before the chemical treatment. The chopped fibres were mixed with resins in proportions (10%, 30%, and 50%) respectively and then with catalyst and accelerator. The mould cavity was lined with polyvinyl alcohol (PVA) to allow for easy removal of the fabricated composite and the mould is allowed to dry. The fibre samples were each allowed to soak adequately in the thermoset resins at room temperature for about 2 hours and then allowed to cure in the inner cavity of the mould which has dimension 160 x 12.5 x 6 mm.

Exposure environments

The samples of approximate dimensions 36 x 25 x 3 mm okro, Abari and Banana fibre composites of different fibre length (10 mm, 30 mm, 50 mm) and loading fractions (10%, 30% and 50%) respectively were used for the measurements of moisture/water absorption studies (ASTM D 570-98). The corners of the samples were curved to avoid non uniform moisture/water uptake or diffusion. The moisture absorption test samples were placed in a temperature controlled oven where the temperature was maintained at 30 ^oC and then taken out and cooled in desiccators and the weight of the samples were determined fibre reinforced composites sample of known dimension were weighed and designated as m_1, before being immersed in distilled water for 24 hours at room temperature.

The specimens were removed, wiped dry with absorbent paper and immediately weighed and designated as m_2. The percentage gain of moisture/water were evaluated using the expression

$$Q=[(M_2-M_1)/M_1] \times 100$$

Differential Thermal Analysis

The temperature program of a differential scanning calorimeter DSC is designed such that the composite sample holder temperature increases linearly as a function of time. Generally the composite samples were crushed into smaller particles. The crushed sample mass was determined. The sample was placed on the circle sensor-inside the DSC furnace and the reference crucibles. The inert gas flow rate was set at 60 ml/min, the purge gas at 60 ml/min and the protective gas at 150 ml/min. The DSC equipment was switched on and the temperature of the samples was in the range 20 ^{0}C to 600 ^{0}C.

Scanning electron microscopy

The scanning electron microscope (SEM) is a type of microscope that uses electrons rather than light to form an image. The advantages of using the SEM instead of light microscope is the large amount of the composite sample that will be in focus at a time and produces images of high resolution which means that small spaced features will be examined for a highly crushed composite sample producing signals that contain valuable information about the external morphology of the composites to determine the extent of fibre-matrix bonds interaction and adhesibility.

RESULTS AND THE DISCUSSION

Moisture/water uptake:

Most polymers are known to take up several percent of water by mass depending on their chemical composition. The equilibrium and rate of sorption are of interest because they strongly influence both the thermo-physical properties and the viscoelastic response of the polymer composites. The results for the moisture/water absorption rate show that epoxy thermosets reinforced with okro (hibiscus esculentus) fibre has the lowest water/moisture sorption rate of 0.2354% (table 1.0) and polyester thermosets reinforced with Abari (uremia lobata) fibre has the highest moisture/water sorption rate of 2.3% (table 1.0) for optimum fibre length of 10 mm and fibre volume fraction of 10%. The lowest moisture sorption rate for okro-epoxy composites is 0.2354% occurring at a fibre length of 50 mm and fibre volume fraction of 12%.

The SEM Images for the nine polymer composites are shown on Figure 1 (Abari-Polyester Composite), Figure 2 (Abari-Epoxy Composite, Figure 3 (Abari-Vinyl Ester Composite), Figure 4 (Banana-Polyester Composite), Figure 5 (Banana-Epoxy Composite) Figure 6 (Banana-Vinylester Composite), Figure 7 (Okro-Polyester Composite), Figure 8 (Okro-Epoxy Composite), Figure 9 (Okro-Vinylester Composite),with Banana-epoxy (Figure 5) composite having the cleanest morphological feature which manifested in their having the highest Tensile strength of 1127 N/mm^2. The least in cleanability of morphology is the okro-polyester reinforced polymer composite (Figure 7) which has the lowest tensile strength of 22.56 N/mm^2.

Table 1: Optimum Moisture/water absorption

Type of Composite	Optimum fibre length (mm)	Optimum Vol fraction (%)	water uptake (%)
Banana-polyester	10	10	1.4440
Banana-Vinylester	10	24	1.003
Banana-epoxy	50	18	0.4585
Okro-Polyester	42	10	2.2600
Okro-Vinylester	50	26	1.432
Okro-Epoxy	50	12	0.2354
Abari-Vinylester	10	10	2.399
Abari-Vinylester	42	24	1.978
Abari-epoxy	10	10	1.1600

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Figure 1 : Abari + Polyester Composite

Figure 2: Abari-Epoxy Composite

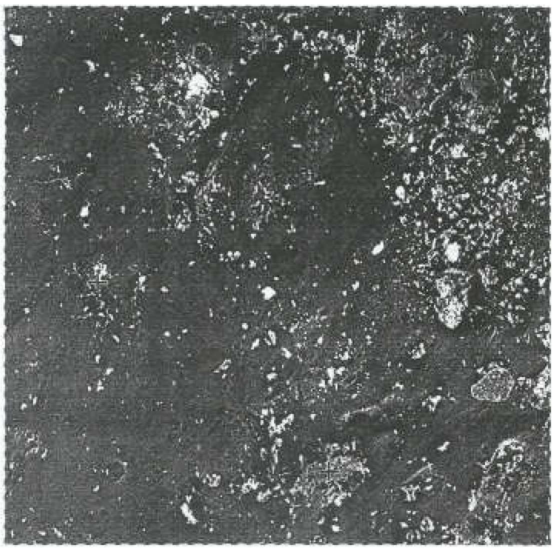

Figure 3: Abari-Vinyl Ester Composite

Figure 4: Banana + Polyester Composite

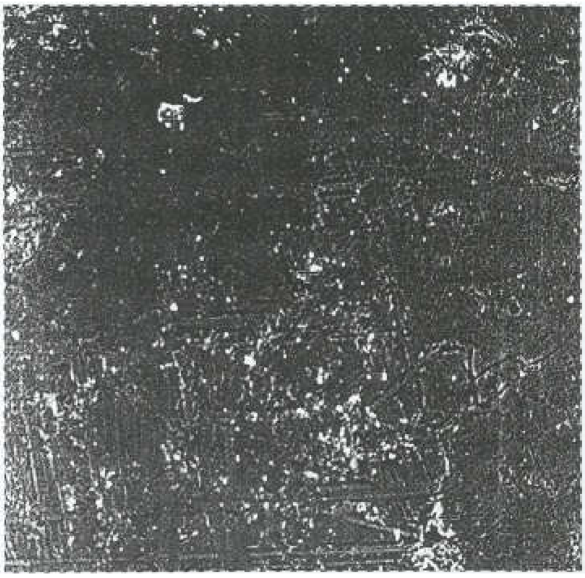

Figure 5: Banana-Epoxy Composite

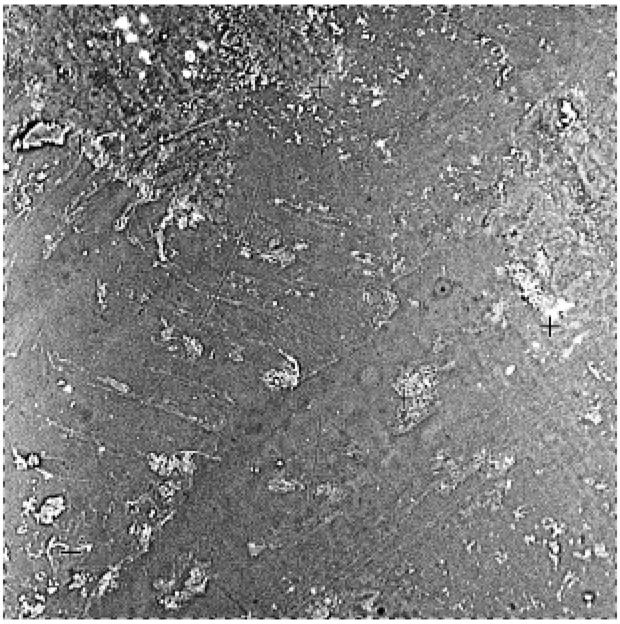

Figure 6: Banana-Vinyl Ester Composite

Figure 7: Okro + Polyester Composite

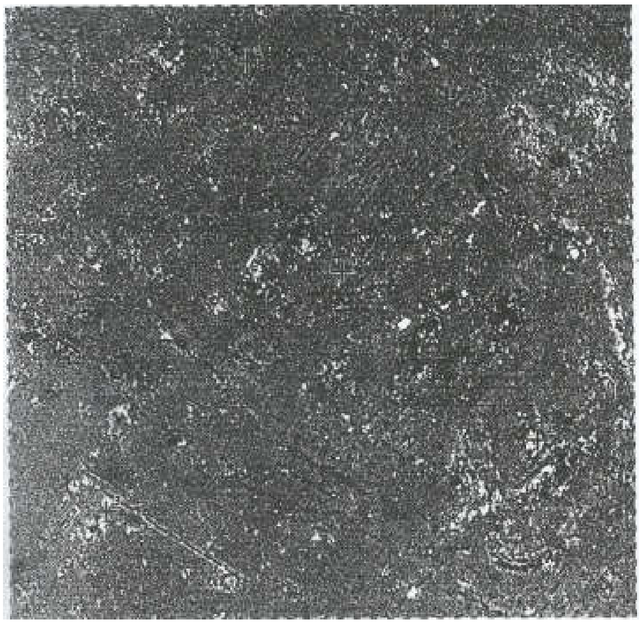

Figure 8: Okro-Epoxy Composite

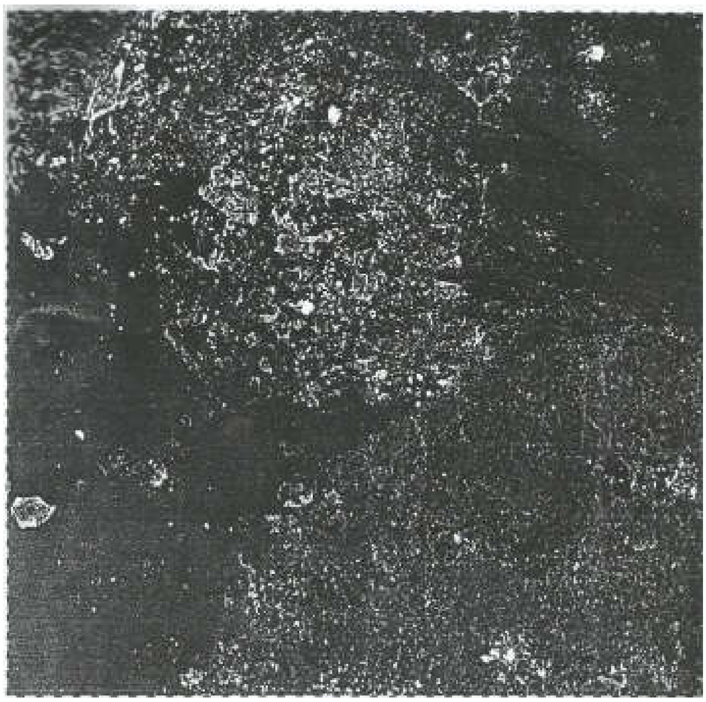

Figure 9: Okro Vinylester Composite