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COMBINED EFFECTS OF WATER ABSORPTION DUE TO WATER IMMERSION, SOIL BURIED AND NATURAL WEATHER ON MECHANICAL PROPERTIES OF KENAF FIBRE UNSATURATED POLYESTER COMPOSITES (KFUPC)

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ABSTRACT

Kenaf Fibre reinforced composites have been gaining wide use in the variety of applications. The performance of these composites may suffer when the material is exposed to adverse environments for long periods of time. Kenaf fibre unsaturated polyester composites (KFUPC) were subjected to three environmental tests: water immersion, soil buried and natural weather tests, in order to study the effect of water/relative humidity absorption on the mechanical properties of specimens containing 10, 20 and 30% by weight of fibre content. Tensile strength and modulus of the composites were determined. A decrease in tensile properties of the composites was demonstrated, showing a great loss in mechanical properties of the humid samples compared to the dry samples. The percentage of moisture uptake increased as the weight percentage of fibre is increased due to the high cellulose content. The water absorption pattern of these composites was found to follow Fickian behavior.

Keywords: Polyester kenaf composite; Water immersion, Soil buried, Natural weather

1. INTRODUCTION

In recent years natural fibre composites were used in many engineering applications due to various desirable properties that they offered such as light weight, renewability, low cost and environmentally friendly. Natural fiber composites are used in many industries such as automotive, sporting goods, marine, electrical, construction, and household appliances (Wallenberger & Weston 2004). Kenaf, sisal, coir, banana, jute flax, pulp, wood flour, oil palm, pineapple leaf and coir are the main natural fibres used as reinforcement (Rowell et al.1997). Kenaf fibres provide high stiffness and strength values. They also have higher aspect ratios making them suitable to be used as reinforcement in polymer composites (Sanadi et al. 1995). Kenaf (Hibiscus cannabinus, L. family Malvaceae) is an herbaceous annual plant. Kenaf is a warm-season annual row crop. The attractive features of kenaf fibres are the low cost, lightweight, renewability, biodegradability and high specific mechanical properties. Kenaf has a bast fibre which contains 75% cellulose and 15% lignin and offers the advantages of being biodegradable and environmentally safe (Mansur & Aziz 1983). Kenaf fiber has superior flexural strength and excellent tensile strength which make kenaf a good candidate for many applications (Aji et al. 2009). However, it has some disadvantages, including high absorption of moisture, which negatively affects the mechanical properties (Coutinho et al. 1997; Rowell et al.1999). The incompatibility between the hydrophilic fibres and hydrophobic thermoplastic and thermoset matrices requires appropriate treatments to enhance the adhesion between fibre and the matrix (Gassan & Cutowski 2000; Dhakal et al. 2007).
Natural weathering is generally carried out to determine durability of the material in natural condition (Stark & Matuana 2006). The idea was to determine the extent on biodegradability possessed by the composite when exposed to natural weather. Sunlight, rain and dew are common parts of natural weathering. Ultraviolet (UV) rays from sunlight were reported as the most common cause of polymer article failure during natural weathering (Schier 2000). Chalking, yellowing, cracking, brittleness and loss of transparency are common observation faced with conventional polymers exposed to natural weather (Schier 2000). Unsaturated polyester has been a popular thermoset used as polymer matrix in composites (Aziz et al. 2005), (Aziz & Ansell 2004).

For current work, unsaturated polyester resin Trade Name Reservol P9509 supplied by Revertex (Malaysia) Sdn. Bhd. Company. It is convenient for hand lay-up application and easy air release. All polymer composites absorb moisture in humid atmosphere and when immersed in water. The effect of absorption of moisture leads to the degradation of fibre-matrix interface region creating poor stress transfer efficiencies resulting in a reduction of mechanical properties (Yang GC et al. 1996). One of the main concerns in the use of natural fibre reinforced composite materials is their susceptibility to moisture absorption and the effect on physical and mechanical properties (Thwe & Liao 2002). Therefore it is important that this problem is investigated in order that natural fibre may be considered as a viable reinforcement in composite materials.

2. EXPERIMENTAL

2.1 Materials

2.1.1 Kenaf bast fibres:

Long kenaf bast fibres obtained from Department of Biological and Agricultural Engineering, Universiti Putra Malaysia was used in this study. Kenaf fibres were dried for 3 hours at 100o C using vacuum oven to remove storage moisture before use. To improve the mechanical properties of the composites kenaf fibre was treated with 6% of sodium hydroxide (NaOH) solution similar to that of the work of Gomez et al. (Gomes et al. 2004).

2.1.2 Resin

The matrix material used in this study was based on unsaturated polyester resin with the trade name of Reservol P9509 supplied by Revertex (Malaysia) Sdn. Bhd., Kluang, Johor, Malaysia. This type of resin is a rigid, low reactivity, thixotropic general purpose orthophthalic the matrix was mixed with curing catalyst, methyl ethyl ketone peroxide (MEKP) at a concentration of 0.01 w/w (weight ratio) of the matrix for curing. Unsaturated polyester have many advantages compared to other thermosetting resins including room temperature, low pressure molding capabilities which make it particularly valuable for large component manufacturing at relatively low cost (El-Sayed et al. 1995).

2.2 Methods

2.2.1 Specimen's fabrications:

A combination of hand lay-up and compression molding method was used to prepare the KFUPC samples. A measured quantity of unsaturated polyester resin mixed with 0.01 w/w catalyst (MEKP) for rapid curing was poured on the kenaf fibre, placed in a mould. The mould was closed and the composite was left to cure under pressure at a temperature of 50oC for about 1h. The mould was opened and the composite was removed from the press. The schematic of a mould press used to consolidate composite panel is shown in Figure 1. Tensile test specimen with the dimensions of 250 x 15 x 2 mm was prepared according to ASTM D3039 as shown in Figure 2 and the environmental test specimens were cut.

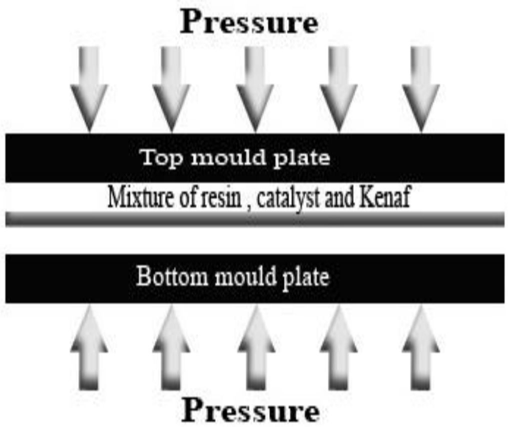


Figure1 Schematic of a mould press used in composite consolidation

2.2.2 Water immersion test:

The water absorption test was carried out as described by ASTM D570. Specimens with dimensions of 62 x 62 x 1 mm shown in Figure 2 were labeled as WSW and immersed in distilled water alongside with tensile test specimens for four months. Then the samples were collected every 10 days and dried to a constant weight at 40 ^{o}C. The percent moisture content/weight gain Mi is calculated by the following equation:

$$M_i = \left(\frac{W_i - W_b}{W_b} \right) 100$$

Where

$M_i =$ Percentage weight gain, g

$W_i =$ Weight of the specimen at time (t)

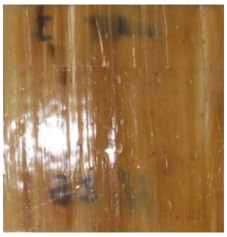
$W_b =$ Baseline mass (oven dry specimen mass), g

2.2.3 Soil buried test:

The soil burial test was carried out as described by (Tserki et al. 2006). Specimens with dimensions of 30 x 30 x 1 mm shown in Figure 2 were labeled as SAS and buried in soil alongside with tensile test specimens for four months for water absorption study. Buried samples were kept at room temperature and watered every 2 days. The samples were then collected every 10 days and washed with water and dried to a constant weight at 40 ^{o}C and the percentage of moisture content per weight gain Mi is calculated.

2.2.4 Natural weathering test:

Natural weathering test was carried out as described in ASTM D1435. Sample dimensions were 30 x 30 x 1 mm labeled as NNW and exposed to atmosphere at an open area at the Strength of Materials Laboratory, Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia alongside with tensile test specimens for four months. Then the samples were collected every 10 days and dried to a constant weight at 40 ^{o}C, and the percentage of moisture content per weight gain Mi is calculated.



Water absorption test sample ASTM D570

Soil and Natural weather test sample ASTMD1435

Tensile test sample with taps ASTM D 3039

Figure 2 Schematic of environmental samples and tensile test sample

3. RESULTS AND DISCUSSION

3.1 Water absorption

Figure 3 shows the behavior of moisture up-take of the SAS, WSW and NNW samples. Initially all samples had sharp linear increase in moisture absorption and reached their saturation state with maximum moisture content of 2.13%, 1.67% after 1440 hour for SAS and WSW respectively. Whereas NNW samples reached saturation state and maximum moisture content of 0.13% after 720 hours, following Fickian diffusion process (Rashdi et al. 2009). It is observed that the overall amount of moisture absorbed from natural weathering was too low, less than 1%g compared to soil buried and water immersion samples.

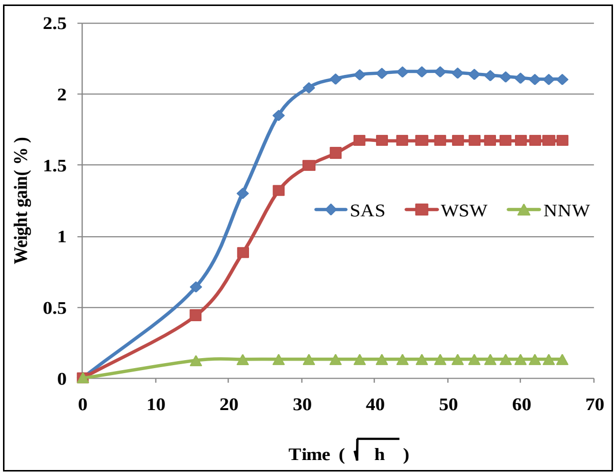


Figure 3 Weight-gain of *KFUPC* specimens versus the square root of time

Figure 4 shows the behavior of moisture up-take for the tensile samples test with 30%wt for all condition tests, from the process of weight gain due to moisture up-take, it is observed that all samples had sharp linear increase in moisture absorption. The soil buried samples S and water immersion samples W reached their saturation state with maximum moisture content of 2.26% and 2.55% respectively after 2160 hours. KFUPC samples exposed to natural weather had lower moisture up-take compared to KFUPC soil buried and water immersion samples.

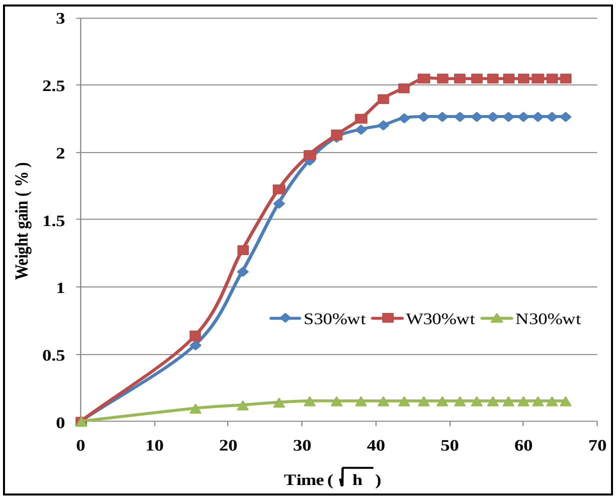


Figure 4 Weight-gain of 30%wt *KFUPC* specimens versus the square root of time

The same scenario is observed for the KFUPC tensile samples test with 20%wt (Figure 5) and 10%wt (Figure 6) for all environmental conditions. Initial sharp linear increase was initially observed in moisture gain and then almost steady moisture up-take for all conditions. *KFUPC* samples exposed to natural weather had lower moisture up-take compare to *KFUPC* soil buried and water immersion samples. After saturation point steady rate of moisture up-take was noticed and no degradation phenomena were observed through all environmental process. Moisture up-take was high for *KFUPC* with high fibre content.

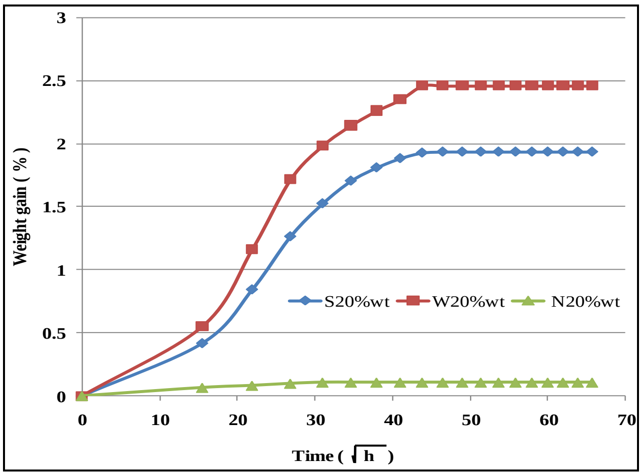


Figure 5 Weight-gain of 20%wt *KFUPC* specimens versus the square root of time

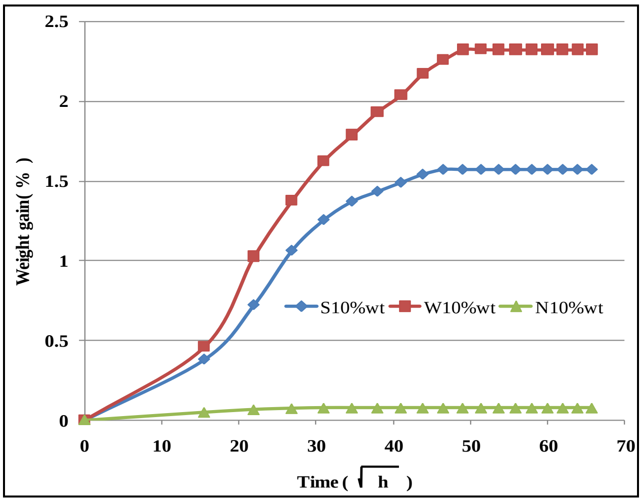


Figure 6 Weight-gain of 10%wt *KFUPC* specimens versus the square root of time

3.2 Effects of moisture absorption on mechanical properties of KFUPC.

To study the effects of moisture absorption on mechanical properties of KFUPC tensile tests were performed for group of dry specimens and for samples of soil buried, water immersion and natural weather after four months of moisture exposure. Figures 7- 9 present these results. Obviously, tensile strength of KFUPC composite dramatically dropped compared to dry samples. The moisture uptakes, due to the humidity, change the structure and properties of the fibres, matrix and the interface between them.

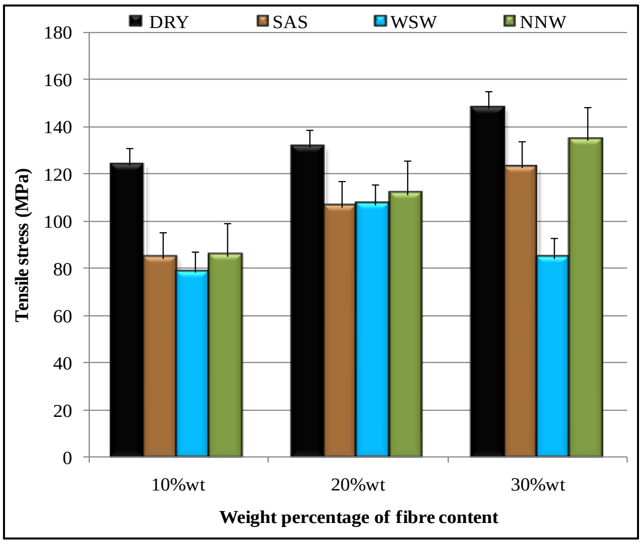


Figure 7 Tensile stresses versus the weight percentage of fibre

It is observed that the tensile stress increased as fibre content was increased for all KFUPC samples. The tensile stress dropped compared to dry samples due to moisture up-take. High fibre content in the sample leads to more water penetration into the interface through the micro cracks induced by swelling of fibres creating swelling stresses which leads to composite failure (Alexander et al. 2004). For 30%wt KFUPC samples, water immersion samples strength dramatically dropped to 84.3 MPa compared to other samples (see Table 1and Figure 7).

Table 1 Tensile strength and Young's modulus of *KFUPC*

KFUPC		Tensile Strength (MPa)	Young's Modulus (MPa)
10%wt	Dry	123.82295	106.083734
	SAS	84.2576375	6401.84838
	WSW	78.20349	85.8493291
	NNW	85.1371933	89.8703383
20%wt	Dry	131.450133	128.370545
	SAS	105.95482	5672.43272
	WSW	106.80922	128.095753
	NNW	111.424067	125.94907
30%wt	Dry	147.9828	150.158837
	SAS	122.577175	7505.5658
	WSW	84.3282	131.986666
	NNW	134.18992	251.048177

This might suggest that volume fraction of kenaf fibre did not reach a minimum value which ensures fibre-controlled composite failure rendering to matrix dominated failure (Huda et al. 2006; Iannace et al. 1999). The presence of voids might also be a contributing factor for the drop in tensile strength at lower kenaf fibre volume (Hill et al. 2000; Facca et al. 2006). Generally, it is found that tensile stresses slightly decreased due to environmental effects for all KFUPC compared to dry samples, but tensile stresses somewhat increased as kenaf fibre content increased. However the polyester resin may play an important role by blocking and reducing the water penetration into the interface through the surface and for high fibre content samples, high amount of water causes swelling of the fibres, which could fill the gaps between the fibre and the polymer-matrix and eventually could lead to an increase in the mechanical properties of the composites (Karmakar et al. 1994). It was observed that strain at maximum load decreased for all environmental KFUPC samples. The maximum strain is also reduced with higher fibre content as shown in Figure 8.

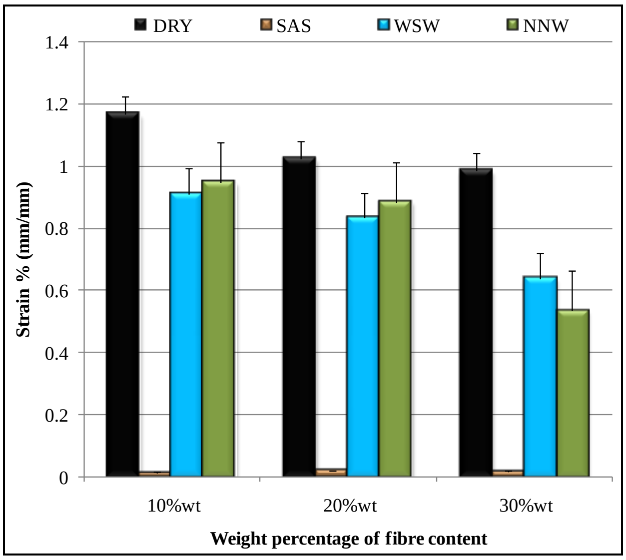


Figure 8 Strain of *KFUPC* versus the weight percentage of fibre

Figure 9(A-C) shows the behavior of the stress strain curves for all the KFUPC. It was observed that stresses decreased as the water absorption increased compared to dry specimens. Moisture up-take from water immersion dramatically affects the mechanical properties of the KFUPC. The influence of fibre contents is such that the tensile stress increased as the fibre content increased.

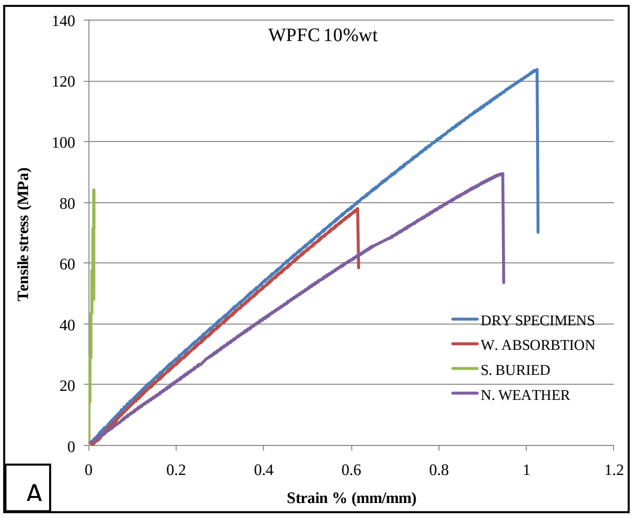


Figure 9A Average stress strain carve of 10%wt *KFUPC*

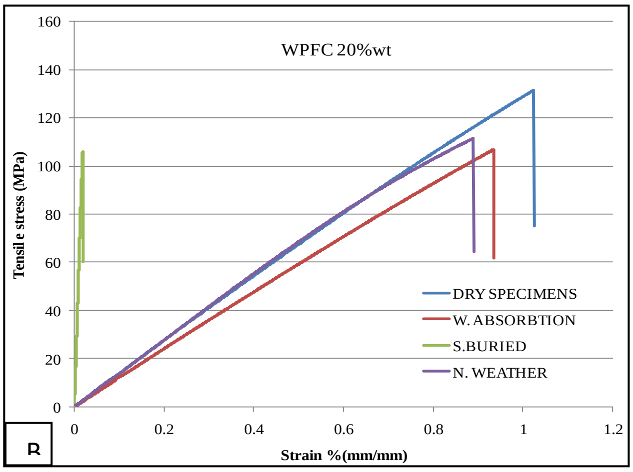


Figure 9B Average stress strain carve of 20%wt *KFUPC*

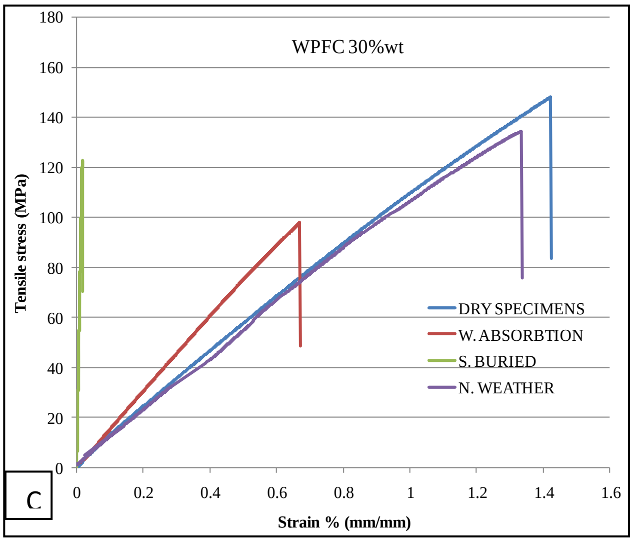


Figure 9C Average stress strain carve of 30%wt *KFUPC*

4. CONCLUSIONS

The effect of natural weathering on mechanical properties and durability of kenaf fibre reinforced unsaturated polyester composite *KFUPC* was studied based on soil buried water immersion and natural weathering. Weight percentage of fibre content plays a role in the rate of moisture uptake and overall uptake at saturated points of *KFUPC* composites. Increasing the weight percentage of fibre content leads to the increase in the tensile properties of the composites for dry specimen, whereas increasing the weight percentage of fibre content leads to the decrease in the tensile properties of the composites for immersed specimen. Thus, KFUPC composites samples differ in their ability to absorb relative humidity. Among all the KFUPC composites tested, it was observed that relative humidity was higher in case of water immersion, and soil buried, whereas in case of natural weather the effects of RH was slightly lower, leading to high tensile strength, which suggests that *KFUPC* can be good candidate for outdoor applications. No significant effect on the mechanical properties of the composite due to the degradation after the samples were buried in soil as it needs long time to degrade. The water absorption pattern of these composites is found to follow Fickian behavior.

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