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Water Absorption Properties of Kenaf/Glass Reinforced Unsaturated Polyester Composites used in Insulator Rods

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Abstract: ***Kenaf fibres have acquired enormous attention in recent years, owing to their economic viability and environmental acceptability. Kenaf (natural) fibres have been started to replace the glass fibre (synthetic) in mechanical, electrical applications and have been utilized in several applications of industrial engineering. The current study deals with water absorption of kenaf/glass fibre reinforced unsaturated polyester composite materials used in high voltage polymeric insulator rods. The kenaf/glass hybrid composites were based on 20%, 30% and 40%(by volume) of kenaf fibers replacement glass fibres with modified 60 vol.% unsaturated polyester resins. The composites were immersedin distilled water at room temperature, and composites resistance to water absorption in terms of the rate of water absorption was determined.A considerable difference in the properties of water absorption of the hybrid composite was found demonstrating that the water absorption effect on the characteristics of insulator rods depends on the arrangement and volume fraction of kenaf fibre of the composite used. Based on the results obtained, a slight effect of water absorption on pure glass fibre composite (control) was observed. The addition of kenaf fibre on glass fibre composite rod increased the water absorption of the composite. It was shown that glass fibres surrounding kena ffibre reduced water absorption. Despite the fact that 40 vol.% of kenaf fibre composite had the highest natural fibre content, it showed the lowest water absorption because of its arrangement on all composite diameters, and also because of being surrounded by glass fibres. All of the materials reached equilibrium and ceased to absorb water after 300 hours.***

Keywords: Kenaf Fibre; Glass Fibre; Insulator Rod; Hybrid Composite; Water Absorption.

I.INTRODUCTION

Nowadays, natural fibre is a significant kind of new renewable reinforcement being used in polymeric composite materials[1]. Because of their lightweight, low cost, and exuberance as renewable resources, natural fibres have acquired circulation over synthetic fibres[2–7].

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Researchers and industries began to prefer natural fibres with good properties because of their plentiful applications such as automotive, furniture, texture, air cleaner, and dielectric manufacturing[8].Kenaf, as one of these types, is economically meaningful and environmentally friendly.

In addition to the fact that kenaf has a short growth period, it has the ability to absorb carbon dioxide[7]. Polymer insulator rods become a prevalent substitution to porcelain in the high voltage HV insulator industries[3–8]. Composite insulator rods are utilized in overhead transmission lines in the range 69-735 KV[6]. Fibre reinforced polymer FRP rods are manufactured by using Pultrusion machine, and fibres are axially aligned with the product line[11]. Despite the benefits (ease of installation, good resistance of impact, flexibility, and high mechanical strength) that FRP offer in comparison with porcelain insulator rods, it can mechanically fail by a fracture in service. Brittle fracture is one of the mechanical fails[10]. The water inside FRP can turn into nitric acid[7-9] causing brittle fracture[14].

The entire surface of the insulator rod is protected by a layer of rubber alloy with multi-kinds of weather sheds as shown in Fig.1. In particular circumstances, the FRP insulator rods can be unprotected and allow moisture to get into the composite. This can happen when the end-fitting of the insulator is uncovered against moisture[10,11].

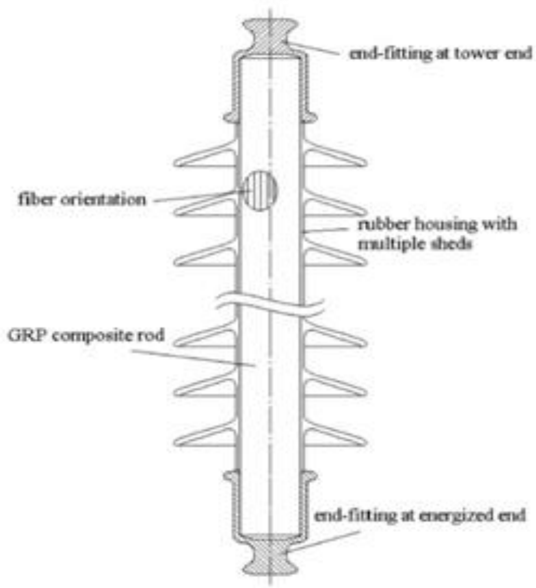

Fig. 1 Schematic of composite insulator [17]

In other cases, when the thickness of the rubber-housing layer is insufficient or damaged by erosion, the FRP rod can be susceptible to water ingress[14]. However, the fracture will occur only when the acid concentration is high. Alternatively, water spreads out along FRP insulator rodleading to electrical failures[14]. The electrical properties of non-ceramic insulator rods have relied heavily on the amount of water absorbed[18]. In order to assess the consequences of water absorption on electrical properties of the composite insulator rods, the amount of absorbed water needs to be defined.

Kumaso et al. [14] have studied the moisture absorption of glass/polymer composite utilized in non-ceramic insulator rods. They have reportedthat water absorption is strongly dependent on the composite geometry. Akil et al. [5] have studied environmental effects on the mechanical properties of jute/glass fibre hybrid composite reinforced polyester, they have conducted, when a design of composite with kenaf fibre in the center of cross-section surrounded by an outer layer of glass fibre reduced the water absorption up to 1000 h.

The resistance of hybrid composite materials to water absorption can be evaluated by numerous experimental procedures[14–16]. In this study, water absorption of kenaf/glass reinforced polyester hybrid composite used in non-ceramic insulator rods was investigated experimentally. The composites were then compared with glass fibre insulator rods (control).

II.MATERIALS

2.1 Kenaf Fibre(KF)

Kenaf fibre has the possibility to be used as a replacement for other conventional fibre reinforcement materials in composites. Recently, Kenaf fibres are quite promising to be the top essential goods in Malaysia under the supervision of the Malaysian National Kenaf and Tobacco Board[22]. Kenaf fibres have certain properties such as stiffness, flexibility,biodegradability and impact resistance that makes it an attractive fibre reinforced polymer composite [23]. Kenaf fibres are created from the bast of the stem of Kenaf plant (a family of Malvaceae) that needs less water to grow. Within four to five months, it normally reaches up to 3-4 meters and could grow three times annually. Economically, Kenaf is cheap among other natural fibres and relatively commercially available. Physical and mechanical properties of Kenaf fibreare shown in Table 1.

Table. 1 Physical and mechanical properties of Kenaf fibre[19, 20]

Density (g/cm^3)	Specific gravity (g/cm^3)	Diameter (μm)	Tensile strength (MPa)	Young's modulus (GPa)	Elongation to break (%)
1.19 – 1.4	1.04	17.7 -100	295 - 930	22-53	1.5 - 6.9

2.2 Glass fibre (GF)

Glass fibre (GF) has been produced by melting glass marbles at nearly 1260 ºC (2300 ºF), then drawing the blend via bushing (usually made by platinum) with rapid cool-down. An additional drawing is made to size the fibres. These fibres are combined into a strand then furled onto a spool. "E-glass" and "S-glass" are the main types of glass fibre. Whereas E-glass has high electrical resistivity and it is named (electrical glass), while S-glass has high tensile strength so named (structural glass). Generally, glass fibre is isotropic. Table 2 shows some physical and mechanical properties of E-glass fibre.

Table. 2 Physical and mechanical properties of E-glass fibre[9, 21]

Density (g/cm^3)	Specific gravity (g/cm^3)	Diameter (μm)	Tensile strength (MPa)	Young's Modulus (GPa)	Tensile Elongation (%)
2.62	2.06	3-20	3450	72	4.8

2.3 Unsaturated Polyester

Polymer materials can be divided into two types of polymer systems: thermoset and thermoplastic. Unsaturated polyester resin is most widely used for engineering industries. Unsaturated polyester matrix is generally used to fabricate pultruded composite utilizing a pultrusion technicality. UP has used in the significant variety of Kenaf and glass fibre composites applications. In addition, UP resin has a good chemical resistance property. Table 3 illustrates the general mechanical properties of unsaturated polyester.

Table. 3 Mechanical properties of unsaturated polyester resin [19, 22]

Density (g/cm^3)	Tensile strength (MPa)	Tensile Modulus (GPa)	Flexural strength (MPa)	Flexural Modulus (GPa)
1.0-2.0	100-120	25-42	100-130	40-43

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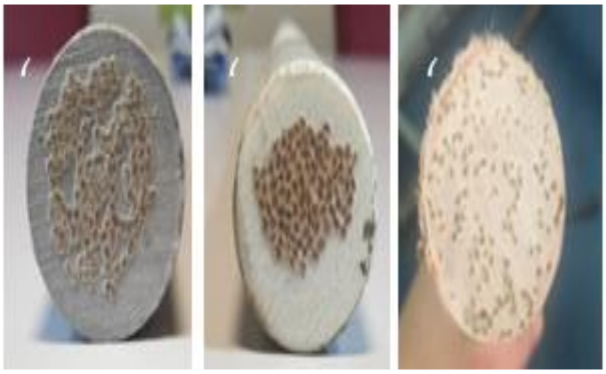
III.EXPERIMENTAL PROCEDURES

3.1 Fabrication of Hybrid Composite

Pultrusion is a continuous process appropriate for manufacturing a composite, which has a consistent cross-section. Usually, the pultrusion process is not required to post-processing; especially when using low-cost fibre reinforced low-cost resin.

In addition to easy processing, pultrusion provides an attractive performance-to-cost ratio. The work-piece is a Kenaf/glass fibre composites reinforced polyester solid round rod fabricated by using pultrusion technique. The fibres saturated by resin are pulled in a PULTREX Px1000-6T automated pultrusion machine at Innovative Pultrusion Sdn. Bhd industry, Seremban, Malaysia. The process started with the support of kenaf and glass fibres. These fibres are pulled into an accurately 24mm as diameter formed to infeed area and impregnated with unsaturated polyester. The material enters the heated die at temp 110 ºC with constant speed (1.7 x 10-2 m/s) and taken out at temp 160 ºC when completely dried. Long continuous fibres and unsaturated polyester resin is supplied by the local market.Fig. 2 illustrates the three types of hybrid composites, (a) 20%, (b) 30%, and (c) 40% (by volume) of kenaf replacement glass fibres reinforced unsaturated polyester by volume fraction.



(a) (b) (c)

Fig. 2 (a) 20%, (b) 30%, and (c) 40% (by volume) kenaf/glass fibre Pultrusion molded samples for water absorption test

3.2 Water Absorption Experiments

The water absorption test steps were carried out according to the proceduresdescribed in detailin ASTM standard D5229/D5229M-92[28]. The specimens were cleaned to remove the remains of machining such as dirt or oil. The specimens mass was measured and recorded initially, and the samples were immediately immersed in distilled water. The change in weight was measured due to irregular time using analytical balance with 0.1 mg accuracy. The specimens were immersed in water until they amount to equilibrium, or a particular behavior was determined.

IV.RESULTS AND DISCUSSION

According to the previous literature review, it is possible thatthe insulator rods that have been in service are uncovered to the environmental conditions. Acids are found on the surface of the insulator generated in moist air, or acid rain may occur from time to time. Depending on the type of composite, failure may occur in case sufficient water is available. Failure of polymer insulator rod could happen when clumps of hardener hydrolyse in the water that is provided from moisture[29].

The amount of water soaked up by specimens was determined using the water absorption test. The test of hybrid composites, which consisted of 20%, 30%, and 40% (by volume) of kenaf/glass fiber reinforced unsaturated polyester pultruded rod was conducted under atmospheric conditions. The results of the composites rod were compared with the glass fibre reinforced polyester round rod (control). Eight specimens (two samples of each type) were tested, and the highest readings were recorded as final results. Fig.3 shows the behaviour of water absorption in composite samples. Initially, all specimens had a dramatic increase in water absorption. After 100 hours, the water absorption had increased sharply until it reached saturation state with entire absorption content 1.59%, 1.63%, and 1.32 % for 20%, 30%, and 40% kenaf/glass hybrid composite respectively. It was found that specimen with kenaf fibre, which is arranged together in core rod had the maximum water absorption, while the specimen with kenaf fibre arranged among glass fibre absorbed less water. Usually, water absorption of the hybrid composite increased with increasing the content of natural fibres[19–23]. Water absorption was also affected by the orientation and arrangement of fibres[29].Generally, the water diffusion in a hybrid composite depends on the type of fibre, exposed and protected fibre surface, matrix viscosity, temperature, and volume fraction[35].

Based on this result, it can be deduced that the existing insulator rod composites (pure glass fibre composite) have absorbed a small amount of water, but hybridization with kenaf fibre increased water absorption. In other words, the fibres do not get completely well attached with resin in the first place but absorb an adequate amount of resin to fundamentally minimize the equilibrium moisture absorption.

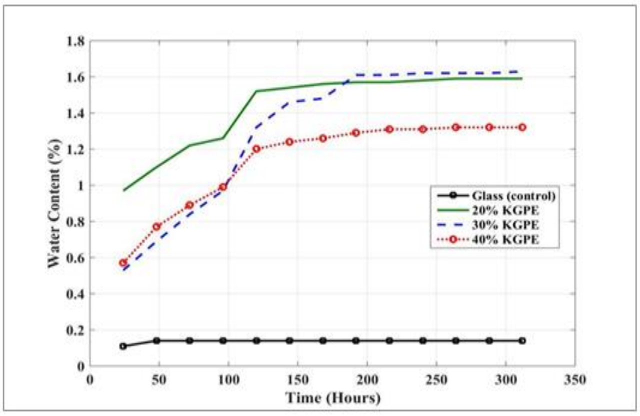


Fig. 3 Water absorption properties of insulator rod hybrid composite

V.CONCLUSIONS

Despite hybridization, natural fibres with synthetic fibres have decreased the cost and weight. Moreover, these fibres are considered environmentally friendly. Nevertheless, this hybridization has a probability of failing because ofunsuitability to hybrid (two different types of) fibres, or swelling caused by water (or moister) absorption.The studyfocuses on the influence of kenaf fibre replacement of glass fibre on water absorption of hybrid composite material. The effect of kenaf percentages (20%, 30%, and 40% by volume fraction) and kenaf fibre arrangement was investigated.

The following findings were inferredfrom this study:

i. The water absorption of glass fibre reinforced polyester (control) was low and did not reach 0.15%.
ii. The addition of kenaf fibres influences water absorption of the composite. Water absorption of kenaf/glass hybrid composite increased 10 times more than glass fibre composite (control).
iii. The effect of the kenaf fibre arrangement was more influential than its content. Whereas 40 vol. % of kenaf replacement glass had the minimum water absorption because kenaf fibres were surrounded by glass fibre, while the 20 vol.% of kenaf fibre had the maximum water absorption because it was concentrated in the core of composite and notcovered by enough glass fibres.
iv. The water absorption of kenaf/glass hybrid composite was minimal and below 2wt. % of the composite weight. It is concluded that the kenaf fibre has a good potential to hybrid with glass fibres reinforced polyester composites.

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