Research Article

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Effect of alkaline treatment on mechanical properties of composites between vetiver fibers and epoxy resin

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Abstract: In this research, we were interested in studying whether vetiver fibers (VFs) treated with different concentrations of sodium hydroxide (NaOH) affect the mechanical properties of VF and epoxy resin (ER) composite material in a better way. As part of the experiment, VFs were treated with NaOH in various concentrations ranging from 0.5, 1, 1.5, 2, 2.5, and 3 mol/L. All of them were molded into composite material in the ratio of 10 wt% with ER. After that, they were tested for mechanical properties such as the tensile strength, impact strength, bending strength, and compressive strength to find the best mechanical properties. In addition, the surface was investigated with scanning electron microscopy (SEM) for adhesion of the VFs with ER. The results of the experiment were not as expected. We found that, increasing the concentration of vetiver treated with sodium hydroxide resulted in a decrease in the mechanical properties of the composite. The best values for impact, tensile, bending, and compressive strengths were 256.42 kJ/m^2, 38.45 MPa, 43.70 MPa, and 110.27 MPa, respectively, and 0.5 mol/L is the best concentration of NaOH for mechanical strengths of the composites. Moreover, from SEM technique, it was found that the mechanical properties decreased at higher concentrations. This may be caused by damage to the VFs due to excessive NaOH corrosion and this point should be taken for further study.

Keywords: vetiver fibers, epoxy resin, alkaline treatment, mechanical properties

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1 Introduction

Nowadays, polymer matrix composites, or materials consisting of a polymer (resin) matrix combined with a fibrous reinforcing dispersed phase, are widely used in military ordnance, construction, and automotive parts industries due to its low cost, low density, ease in processing, and comparable mechanical properties with metal and ceramic [1,2]. However, the polymers in applications generally contain petropolymers which come from unrenewable sources and non-biodegradable polymers [3] as well as the reinforcing materials commonly used are the non-biodegradable glass fibers [4,5]. Therefore, the development of environmental-friendly material has become an interesting research area with the advantages of high strength and modulus, low levels of volatiles, excellent adhesion, low shrinkage, good chemical resistance, and ease of processing [6]; epoxy resins (ERs) are widely used as prepregs and structural adhesives.

Natural fibers have been increasingly used as alternative fillers in many areas of polymer composites [7,8]. Their advantages over synthetic fiber are low cost, less tool wear during processing, low density, environmentally friendly, and biodegradability [9]. Nevertheless, natural fibers also have some limitations such as high moisture absorption and subsequent swelling and degradation, poor chemical and fire resistance, and poor mechanical properties [10–12]. Therefore, surface modifications of natural fibers are required to improve the bonding properties of fibers before they are used as reinforcement in composite materials with good mechanical properties and high strength [13,14]. The process used

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to modify the fiber surface can be divided into two main methods: mechanical method and chemical method [15,16]. As for natural fibers, the alkaline treatment technique is one of the chemical methods often used as the composite material obtained becomes more rigid with less porosity and increased density. The chemical modification of natural fibers is a frequent use of alkaline treatment. The surface roughness is raised as a result of the alkaline treatment's modification or disruption of the hydrogen bonding that holds the system structure together. This is a significant improvement. In addition, the surface modifications also increase the surface tension and roughness [13–17]. Natural fibers which have already been used in polymer composite industry are jute, flax, sisal fibers with vetiver fiber (VF) as one of the interesting candidates because special characteristics of vetiver grass: vetiver grass has many joints on the stem. It can be propagated using shoots all year long. It has long leaves that are easy to cut and grow again. Strong and resistant to degradation. The ER/VF composite looks most promising.

In addition, each type of natural fibers responds differently to the methods and chemicals utilized. And in the case of VF, there is not much information about the treatment to prepare the surface of fibers for use in composites. For this reason, in this work, the authors focused on the effect of alkaline treatment on mechanical properties of VFs and ER composites. The composite samples were prepared using hand lay-up technique. Mechanical properties were investigated and microstructure of samples was determined by scanning electron microscopy (SEM) technique.

2 Materials and method

2.1 Materials

Sri Lanka Ecotype vetiver grass grown in Thailand, analytical reagent grade of sodium hydroxide, and the epoxy and hardener at a ratio of 100:27 by volume were used in our work. The density of the matrix is 1.176 g/cm^3.

2.2 Preparation of VFs

The vetiver leaves were cleaned in running water and sun-dried to remove the moisture. The prepared leaves were chopped and treated with sodium hydroxide (NaOH) solution of various concentration (0.5, 1, 1.5, 2, 2.5, 3 mol/L) for 4 h. The VF was washed by deionized water until the pH level became 7. The leaves were then spun in a blender and sieved into length of 1 mm before mixing with ER.

2.3 Fabrication of the ER/VF composite

The ER and VF were mixed together by hand for 5 min. The ER and VF were mixed together in the ratio of 1:10 by weight with hand for 5 min. The mixture was then sonicated by ultrasonic device for another 5 min, after which the mixture was molded by hand layup technique and left in room temperature for 8 h to settle (Figure 1).

2.4 Characterization method

Tensile strength as per ASTM standard D638-10 [18], bending strength as per ASTM standard D790-03 [19], and compressive strength were measured by a universal testing machine (CAT NO. 2603-080). Impact strength was measured by impact tester with Charpy impact test. And microstructure of composite was studied by SEM (JEOL JSM-5910LV).

3 Results and discussion

The mechanical properties of composite samples are shown in Table 1. It could be seen that the mechanical properties of the composites decreased with the increase in the concentration of NaOH. It could be due to that when fibers are treated in too high concentration of treatment substances, inevitable damage is caused to the fibers. Then, the mechanical properties are lower when fibers was mixed with ER which corresponds to Karthikeyan and Balamurugan [20] and Mouhoubi *et al.* [21]. Besides, according to Hamidon *et al.* [22], excessive delignification of natural fiber can result

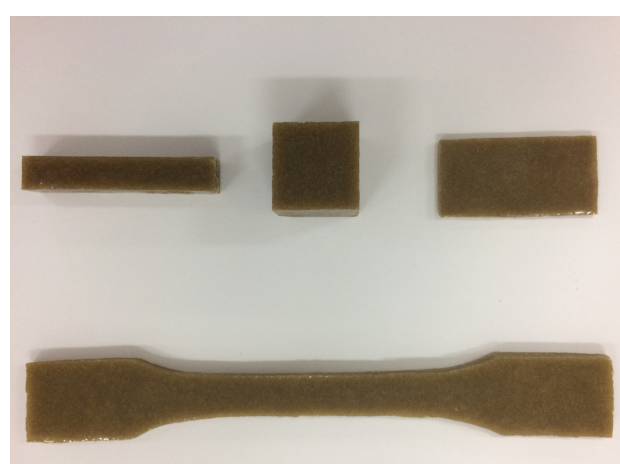

Figure 1: The VF and ER composite samples.

Table 1: Mechanical properties of ER and VF composite treated with NaOH of various concentrations (VFT)

Sample	Impact strength (kJ/m^2)	Tensile strength (MPa)	Bending strength (MPa)	Compressive strength (MPa)
VF + ER	236.64	35.67	35.61	109.44
0.5 mol/L VFT+ER	256.42	38.45	43.70	110.27
1 mol/L VFT+ER	256.28	37.27	42.73	108.66
1.5 mol/L VFT+ER	249.17	35.88	39.55	109.27
2 mol/L VFT+ER	243.64	34.36	38.22	108.22
2.5 mol/L VFT+ER	248.32	34.64	37.22	107.41
3 mol/L VFT+ER	244.87	35.33	35.11	107.78

from a higher percentage of alkaline content, which weakens or destroys the fiber. Increase in the concentration of NaOH has also been observed to significantly reduce the tensile strength of the resulting composite.

The results obtained exhibited that the maximum values of 256.42 kJ/m^2, 38.45 MPa, 43.70 MPa, and 110.27 MPa for the impact, tensile, bending, and compressive strengths, respectively, were obtained at the concentration of 0.5 mol/L NaOH. Moreover, the mechanical properties of 3 mol/L+ER decreased significantly, even less than those of VF+ER, which caused the fiber surface to be destroyed by the surface treatment process.

However, increasing the concentration of NaOH had a greater effect on raising the overall mechanical properties than that of not adding NaOH, except in the 3 mol/L alkali-treated vetiver fibers (VFT) + ER condition. Increasing the surface area or roughness will improve the mechanical interaction of the fiber with the matrix. Then, the alkaline treatment's exposure of the cellulose on the fiber surface

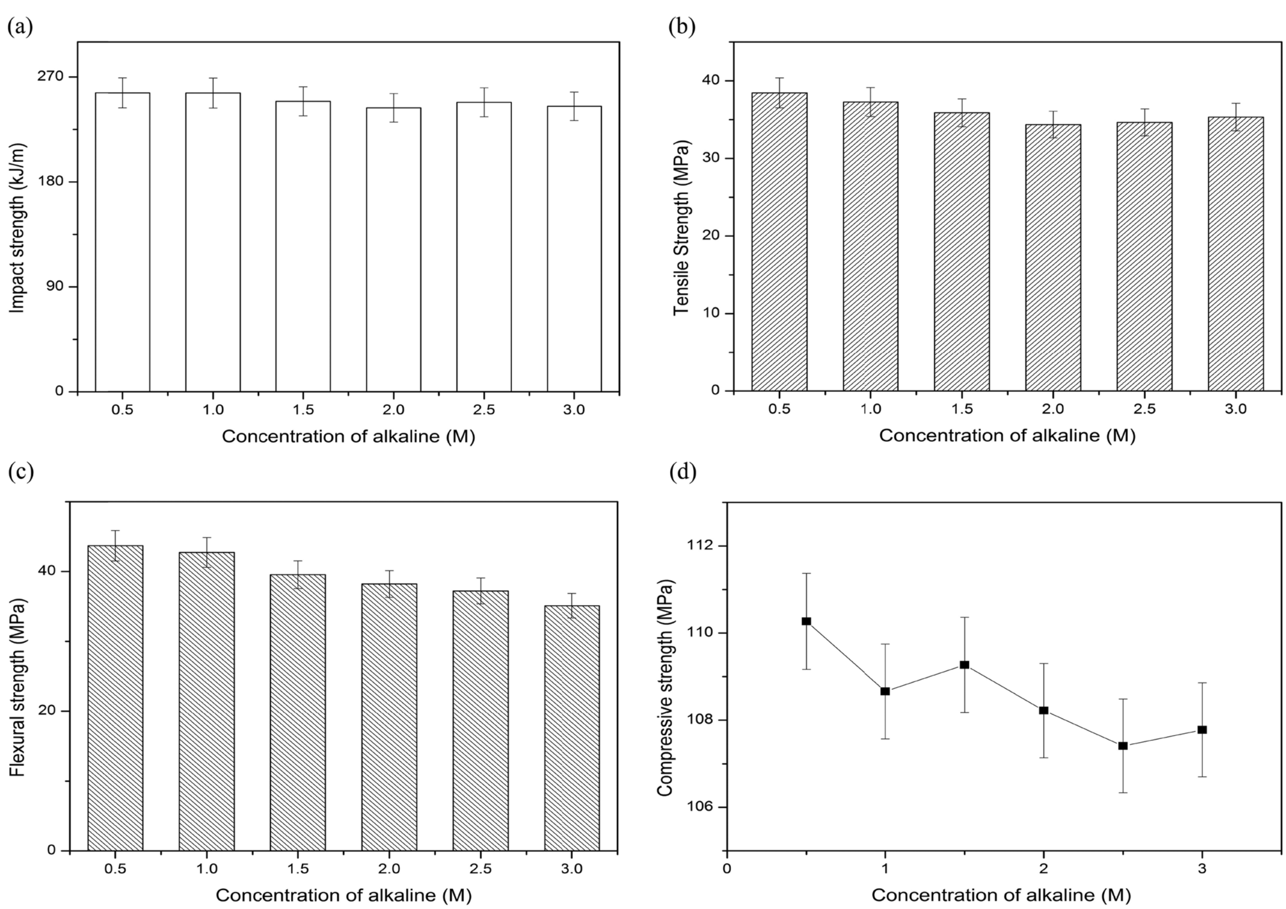

Figure 2: Mechanical properties tested result of composite samples (a) impact strength, (b) tensile strength, (c) flexural strength, and (d) compressive strength.

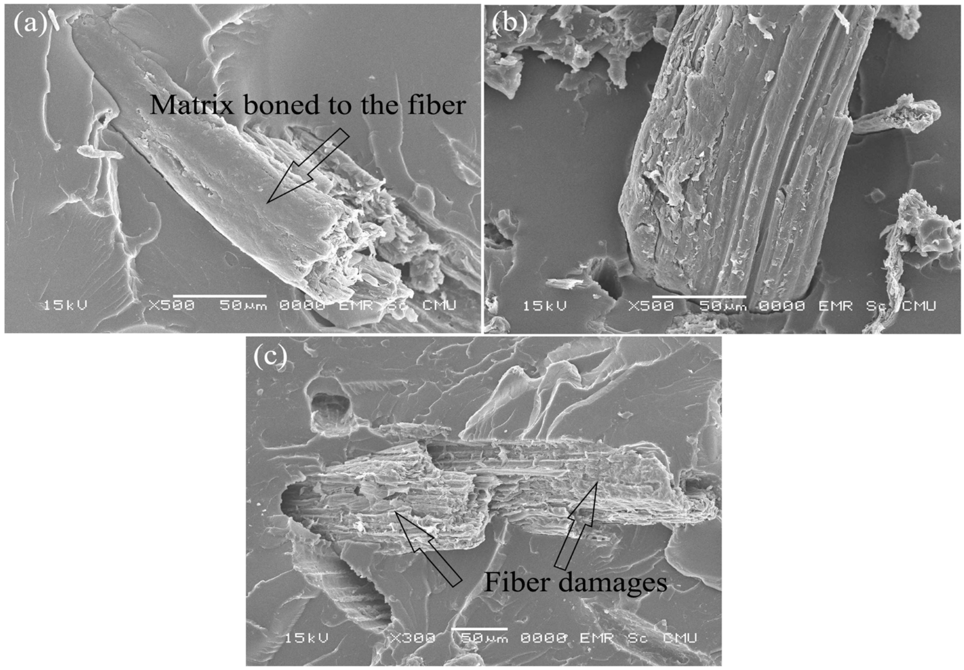

Figure 3: SEM images of composite samples: (a) 0.5 mol/L VFT+ER, (b) 1.5 mol/L VFT+ER, and (c) 3 mol/L VFT+ER.

increases the potential number of reaction sites. Therefore, the alkaline treatment directly affects the cellulosic fibrils, the extraction of lignin, and hemi cellulosic compounds, as well as the level of polymerization which is in agreement with that reported by Prince *et al.* [23].

Impact strengths of the composite samples, measured by Charpy impact test with cross head speed of 10 mm/min, are shown in Figure 2(a). We found that the impact strength of the samples ranged from 243.64 to 256.42 kJ/m^2. From Figure 2(b), it could be seen that the tensile strength of the samples ranged between the values of 26.78 and 38.33 MPa. The maximum tensile strength occurred at the concentration of 0.5 mol/L of NaOH which agreed with that reported by Wong *et al.* [24] that an increase in alkaline concentration reduces the strain at failure and ductility of fiber. Figure 2(c) shows the results of the bending test by universal testing machine with cross head speed of 5 mm/min. The values of flexural strength ran between 35.11 and 43.70 MPa. Therefore, the compressive strength of the sample is 107.41–110.27 MPa.

Finally, the morphology of the composite samples was studied employing the SEM method. The morphology of the best mechanical properties is presented in Figure 3(a). The surface of the fibers and the epoxy matrix are well matched. This makes the gap between the fiber and the matrix smaller. As a result, the mechanical properties are improved. Whereas Figure 3(b) shows the morphology of 1.5 mol/L VF/ER. The SEM image of the composites in Figure 3(c) shows the damage of VF of 3 mol/L VFT+ER. Due to the excessive concentration of NaOH, the inhomogeneous VFs damages result in weak fiber matrix adhesion between VFs and ER, which corresponds to the mechanical property results reported by Oushabi *et al.* [25].

4 Conclusion

The alkaline-treated VFs and ER composites were fabricated using hand layup technique. The obtained composites showed a homogeneous distribution and adhesion between VF and ER. The maximum mechanical properties, *i.e.*, the impact, tensile, compressive, and flexural strengths of the VF/ER composites were obtained when the VFs were alkali-treated in a 0.5 mol/L of NaOH solution for 4 h. At higher concentration of NaOH, the VFs were damaged and the mechanical strengths of the VF/ER composites decreased. However, the VFs have been treated. It still improves the mechanical properties of composite materials more than that of the untreated VFs. But it must be at the right level, which can be applied in other reinforcement materials.

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