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Effect of Alkali Treatment on Mechanical Properties of Sisal Woven Fabric Reinforced Epoxy Composites

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Abstract: *In thiswork, woven sisal fabricrein force depoxy composites werefabricated by hand lay-up technique. To investigate the effect of alkali treatment on the mechanical properties of the resultant composites, the sisal fabrics were soaked in 4% w/v NaOH solution for one hour and pre-dried in an oven at 80^{0}C for one hour before using them in composite fabrication.Specimens for mechanical testing were prepared based on ASTM D638, ASTM D3410, ISO 179:1997 and ASTM D790 standards. From the test results, the mechanical properties of alkali treated composites were found to be higher than those of untreated composites. For instance, the tensile, flexural and compressive strengths increased by 12.59%, 11.36% and 23.46% respectively while the tensile, flexural and compressive moduli of the composites increased by 31.19%, 12.97% and 34.98% respectively as a result of alkali treatment. This shows that alkali treatment of sisal fibres improves the mechanical properties of the resultant composites due to increased fibre-matrix interfacial bonding.*
Keywords: *Alkali treatment, Mechanical properties, Non-structural applications, Sisal Woven Fabric*

I. INTRODUCTION

The increasing environmental concerns and awareness for greenhouse effect and biodegradability have been the main driving force for the shift from synthetic fibre reinforced composites to natural fibre reinforced composites for various non-structural applications. This is because the development and use of natural fibre composites in these applications have least effects on the environment. Natural fibres such as sisal are light-in-weight, low cost, non-toxic, naturally available, renewable, recyclable and biodegradable in nature [1]. Hence, natural fibre reinforced composites seem to provide alternative to man-made synthetic fibres for various non-structural applications such as room partitions, door panels and food packaging due to their resistance to corrosion and chemicals, light-weight and unique functional properties such as damping, low electrical and thermal conductivity [2]. Research on natural fibre reinforced polymer composites has gained much attention from material scientists since they provide suitable alternative to man-made fibres which are expensive and unsustainable as they are obtained from petroleum resources that are ever depleted. Natural fibre reinforced composites are widely used in various non-structural applications. For instance, flax and hemp fibres reinforced composites have been successfully used as packaging materials and interior panels in automobiles [3]. The use of natural fibres in polymer composite fabrication faces challenge of poor adhesion between natural fibres and polymeric matrix due to large moisture absorption in hydrophobic matrix. This significantly affects fibre/matrix adhesion causing premature ageing due to degradation and loss of strength. Alkali treatment eliminates hemicellulose and lignin from natural fibres which are responsible for this problem thereby increasing cellulose content and fibrillation [4]. This improves the mechanical properties of the fibres.

Sisal (*agave sisalane*) is a natural vegetative fibre obtained from leaves of the plant. Sisal is considered as the most widely used natural fibre in the world with the use increasing tremendously in the recent past due to increased awareness for eco-friendly materials. Kenya, the third world producer of sisal after Brazil and Tanzania, produces approximately 28,000 metric tonnes per year [5] which is exported in raw form. Kenya's preferred usage of polymers in packaging, ceiling materials, plastic water bottles and other applications has led to high volumes of plastic wastes dumped in urban centers causing serious threat of environmental degradation such as clogging of water drainage system, land degradation and air pollution when burned. Attempts to recycle these wastes have faced serious challenges due to non-biodegradable nature of these plastics thereby making land disposal most unattractive. The current research work aims at developing sisal fibre reinforced epoxy composites for non-structural applications thus replacing products currently manufactured from plastics and wood. This will add value to locally grown sisal fibres, create job opportunities, reduce environmental pollution and conserve forests.

II. EXPERIMENTAL

2.1. Materials

Woven sisal fabric was sourced from Premier Bags and Cordage Industry, Juja-Kenya. Epoxy resin Lapox B-47 of density 1.06–1.18 g/cm^3 and hardener ARADUR 3486 of density 0.92–0.98g/cm^3 were both purchased from *Araldie City Suppliers*,Nairobi. The epoxy resin and hardener were mixed in the ratio of 5:3 by weight as per manufacturer's recommendations.

2.2. Alkali Treatment

Square sisal woven fabrics each measuring 300mm by 300mm were subjected to alkali treatment of 4% w/v NaOH solution by soaking them in alkali solution at room temperature for one hour thereafter thoroughly cleaned using distilled water to remove alkali residues and other impurities present. The fabrics were then dried in an oven at 80^{0}C for one hour. Alkali treatment served to improve the dispersion of the fibre in the matrix thus improving the degree of bonding between the fibres and epoxy matrix thereby increasing interfacial adhesion. To investigate the effect of alkali treatment on mechanical properties of the resultant composites, some fibres were treated while others were used without any chemical treatment (control samples).

2.3. Composite Fabrication

Prior to composite fabrication, a mould measuring 310mm by 310mm by 10mm and its lid measuring 300mm by 300mm with sufficient stiffness to withstand handling loads were fabricated in the School of Engineering Workshop, Moi University using stainless steel sheet.

Starting with untreated woven sisal fabric reinforcement, composites were fabricated using hand lay-up technique. Using the manufacturer's recommended mixing ratio, epoxy resin and hardener were thoroughly mixed to make the matrix. A thin layer of mould release agent was applied unto the surface of the mould followed by gel coat before placing the weighed sisal fabric layers. The required quantity of the matrix was uniformly applied with a brush and squeezed in using a pressure roller to facilitate uniform impregnation of the fabric with matrix.

A plastic Perspex sheet was placed on the inner surface of the top mould plate followed by spraying of release agent to avoid sticking of the composites. Using a metallic lid, the mould was closed and allowed to cure at room temperature under a load of 30kg (3.3kN/m^2 compressive pressure) for 24-hours to ensure uniform consolidation thus minimizing the number of voids in the resultant composites. The same procedure was used for treated woven sisal reinforcement. In both cases, the composites were processed at 40% fibre weight fraction. After curing, the mould was opened to remove the composites for mechanical testing.

2.4. Mechanical Testing

The composite samples were cut as per the ASTM Standards and conditioned in the Textile Laboratory at RiftValley Textiles (Rivatex) for 48 hours at ambient conditions of temperatures (23±2^{0}C) and relative humidity (65%) before performing any test. Tensile tests were conducted as per ASTM D638 standard using Universal Testing Machine (type TH2730) with crosshead speed of 2 mm per minute and a load cell of 5kN. The tensile modulus and strength were calculated from the stress-strain curve. Compression tests were performed on the same machine as per ASTM D3410. Flexural (three–point bending) test was carried out in accordance with ASTM D790 on a computer controlled Universal Materials Testing Machine with a load cell of 5kN at a crosshead speed of 2mm per minute. Impact tests were conducted according to ISO 179-1:2000 standard on a Charpy impact tester model JB-300w with maximum impact energy of 300J.

III. RESULTS AND DISCUSSION

3.1 Tensile, flexural and compressive strengths

Fig. 1 shows the results of alkali treatment on the tensile, flexural and compressive strengths of the composites.

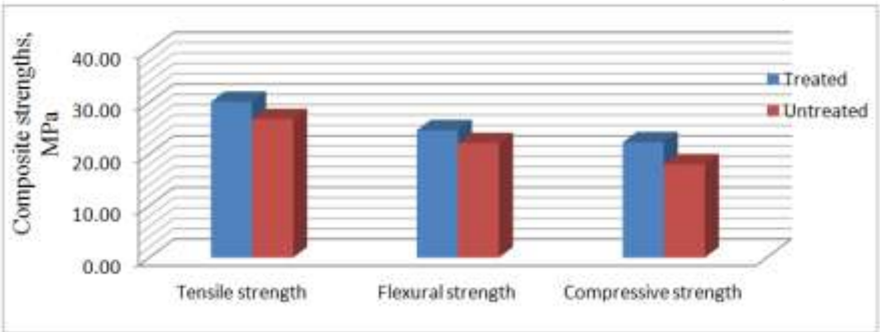

Figure 1: Effect of alkali treatment on the tensile, flexural and compressive strengths of the composites

The study reported improved tensile, flexural and compressive strengths of the composites due to alkali treatment. For instance, the tensile, flexural and compressive strengths increased by 12.59%, 11.36% and 23.46% respectively as a result of alkali treatment. The improved tensile, flexural and compressive strengths reported in this study as a result of alkali treatment is congruent with previous studies on natural fibre reinforced composites [6, 7, 8, 9] and may be attributed to excellent interface between fibres and matrix due to removal of cementing materials such as lignin thus increasing fibre surface area. Also, the improvement in strengths can be explained by improved mechanical interlocking and increased number of possible reaction sites due to increased amount of cellulose exposed on the fibre surface [10]. Therefore, treated composites exhibited improved strengths compared to untreated counterparts.

3.2 Tensile, flexural and compressive moduli

Fig. 2 shows the results of the effect of alkali treatment on tensile, flexural and compressive moduli of the composites.

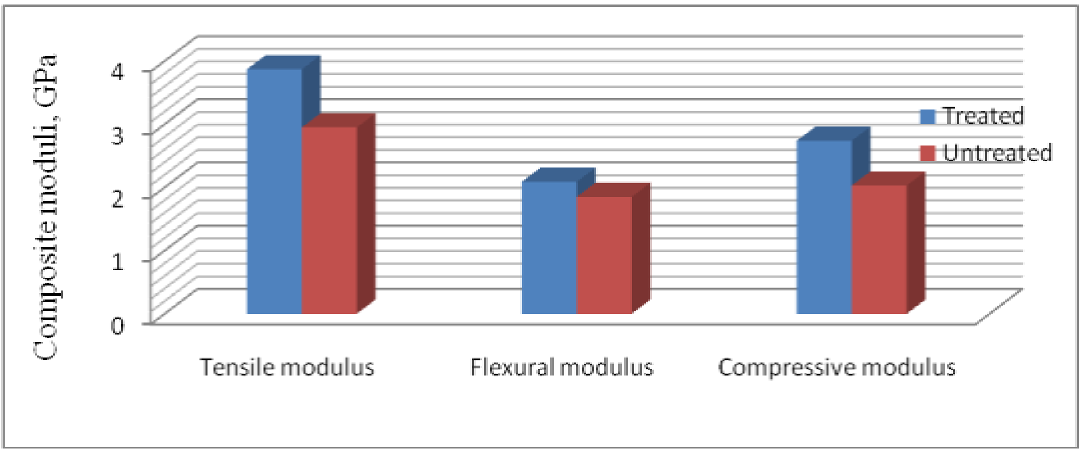

Figure 2: Effect of alkali treatment on the tensile, flexural and compressive moduli of the composites

The study showed that the tensile, flexural and compressive moduli of the composites increased by 31.19%, 12.97% and 34.98% respectivelyas a result of alkali treatment. Therefore, it can be deduced that alkali treatment of the sisal fibres improved the tensile, flexural and compressive moduli of the resultant composites. This observation is consistent with previous studies on natural fibres reinforced composites [11] and can be attributed to increased fibre surface area as a result of excellent interface between fibres and matrix.

3.3 Impact strength

Fig. 3 shows the result of the effect of alkali treatment on impact strength of resultant composites.

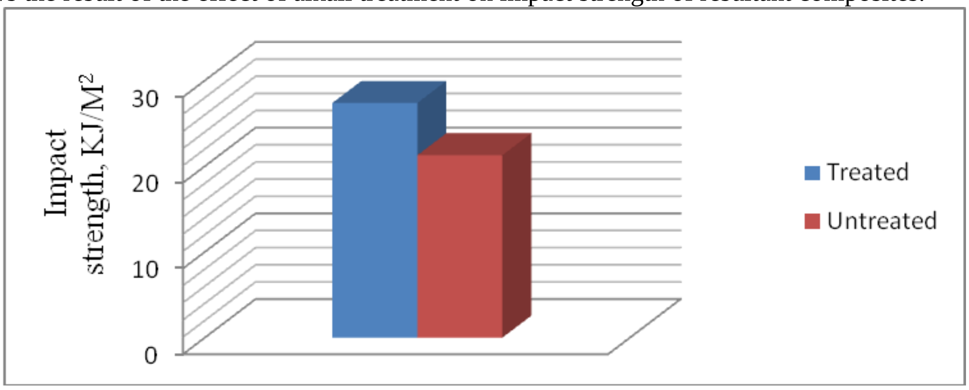

Figure 3: Effect of alkali treatment on the impact strength of the composites

The impact strength results showed that alkali treated composites had higher impact strengths compared to corresponding untreated composites. For instance, the impact strength of the treated composites was 28.67% higher than that of neat composites. The findings are consistent with previous studies on natural fibre reinforced composites [8] and can be attributed to increased energy absorption thus more energy is required to break the specimens resulting into improved impact strengths for treated composites compared to untreated composites. Research has shown that impact response of fibre composites is affected by fibre and matrix properties as well as interfacial bonding strength. The impact energy dissipated during impact testing is caused by fibre pull out, debonding and fibre and/or matrix fracture. Fibre fracture and fibre pull out represent the measure of the interfacial bond strength with fibre fracture showing strong interfacial bond while fibre pull out is an indication of weak bond [12].

IV. CONCLUSION

The mechanical properties of woven sisal fabric reinforced epoxy composites have been investigated. It was observed that alkali treatment of the fibres increased both the strengths and moduli of the composites because alkali treatment of fibres results in better mechanical interlocking due to increased surface roughness. Secondly, alkali treatment of fibres increases number of reaction sites by increasing the amount of cellulose exposed on the surface of the fibres. The mechanical properties of woven sisal fabric reinforced epoxy composites tested show that these composites can replace synthetic composites in various non-structural applications such as wall partitioning, ceiling and packaging that do not require very high load bearing capabilities. The use of sisal fibre reinforced composites in these applications will address global challenges of pollution and emission of greenhouse gases as sisal fibres are biodegradable, renewable and environmentally friendly.

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