International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 6 Issue 11|| November 2017 || PP. 72-75

Effect of Fibre Weight Fraction on Mechanical Properties of Woven Sisal Fabric Reinforced Epoxy Composites

Dennis O. Bichang'a*[1], Hesborn R. Ayub[2]
[1](Department of Manufacturing, Industrial and Textile Engineering, Moi University, Eldoret, Kenya)
2(Department of Industrial and energy Engineering, Egerton University, Egerton, Kenya)
Corresponding Author: Dennis O. Bichang'a

ABSTRACT: *In this work, woven sisal fabric reinforced epoxy composites were fabricated using hand lay-up technique. To investigate the effect of fibre weight fraction on the mechanical properties of the resultant composites, the fraction of sisal fibres in the composites was varied at 30, 40, 45, 50 and 60%. 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 the resultant composites increased with increasing fibre weight fraction (V_{wf}). The tensile and compressive strengths increased from 22.63MPa to 30.91MPa and 15.32MPa to 23.91MPa respectively as fibre loading increased from 30%V_{wf} to 50%V_{wf}; flexural strengths increased from 19.17MPa at 30%V_{wf} to 27.16MPa at 60%V_{wf}; impact strength increased from 17.89KJ/m^2 at 30%V_{wf} to 24.58KJ/m^2 at 45%V_{wf}. This shows that increasing fibre weight fraction improves the mechanical properties of the resultant composites due to increased amount of loading bearing elements, fibres, thus the composites showed increased ability to withstand mechanical loading at higher fibre loadings.*

KEYWORDS**:** *Fibre weight fraction, Mechanical properties, Non-structural applications, Sisal Woven Fabric*

Date of Submission: 25-10-2017 Date of acceptance: 11-11-2017

I. INTRODUCTION

Composites are engineered materials made of at least two constituents with significantly different physical or chemical composition bonded together while retaining their individual identities and properties within the finished structure. Currently, there is increased awareness of eco-friendly materials that are biodegradable with no or less impact on the environment. This has been the main reason why natural fibre reinforced composites are gradually replacing synthetic fibre reinforced composites in non-structural applications such as door panels and room partitions. Besides biodegradability, natural fibres reinforced composites are associated with attributes such as light-in-weight, low cost, non-toxic, naturally available and renewable [1]. Also, natural fibre reinforced composites are resistance to chemicals and corrosion thus providing a sustainable alternative to synthetic reinforced composites. These functional properties of natural fibre reinforced composites is behind extensive research studies conducted in these materials in the recent past in addition to several research studies current underway. On the other hand, extensive research on natural fibre reinforced composites has been necessitated by high cost, non-sustainable and non-biodegradable nature of synthetic fibres such as carbon fibres that are obtained from petroleum products that are depleted [2].

Sisal is a natural vegetative fibre obtained from the leaves of *agave sisalane* plant and considered one of the widely produced and used natural fibres in the world. The global annual production of sisal is estimated at 270,000 metric tonnes (MT) with Brazil, Tanzania and Kenya being the leading producers at 150 MT, 35 MT and 28 MT respectively [3]. However, Kenya's sisal is exported in raw form to more than 30 destinations in the world with major markets being China, Saudi Arabia, Morocco and Nigeria [4]. In Kenya, high volumes of plastic wastes are dumped in most urban centers due to the polymer's preferred usage in packaging, ceiling materials and other applications. These plastics pose a 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 aim of the current research work is to develop sisal fibre reinforced epoxy composites for non-structural applications thus replacing products currently manufactured from plastics and wood. This will result into value addition of locally grown sisal fibres, job creation; and forest and environment conservation.

II. EXPERIMENTAL

- *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.

- *Composite Fabrication*

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

Woven sisal fabric reinforcement was cut in square pieces measuring 300mm by 300mm. These were used in the fabrication of composites using hand lay-up technique. Epoxy resin and hardener were mixed based on the manufacturer's recommended mixing ratio of 5:3 by weight followed by thorough stirring to make the matrix. The fabricated mould was first cleaned and dried to eliminate any dust particles. 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 (see Fig. 1).

Figure 1: Application and squeezing the matrix into the fibres

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. After curing, the mould was opened to remove the composites for mechanical testing. In this study, the fibre weight fraction was varied at 30, 40, 45, 50 and 60% fibre loading.

2.3 Mechanical Testing

The composite samples were cut as per the ASTM Standards and conditioned in the Textile Laboratory at Rift Valley Textiles (Rivatex) for 48 hours at ambient conditions of temperatures (23±2^{0}C) and relative humidity (65%) before performing the mechanical tests.

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

- *Tensile, flexural and compressive strengths*

Fig. 1 shows the effect of fibre weight fraction on the tensile, flexural and compressive strengths of the composites.

Figure 1: Effect of fibre weight fraction on tensile, flexural and compressive strengths of the composites

The reported increased tensile, flexural and compressive strengths with increasing fibre weight fraction. For instance, the tensile strengths of the composites increased by 18.25%, 5.49% and 12.36% as fibre weight fraction increased from 30-40wt.%, 40-45wt.% and 45-50wt.% respectively. This observation is consistent with previous studies [5, 6, 7] and may be attributed to increased amount of load bearing elements (fibres) in the composites as well as better fibre-matrix interface bonding. Thus ensures good stress transfer from the matrix to the fibres. However, the tensile strength reduced by 25.13% as fibre weight fraction increased from 50-60wt.% as a result of reduced wettability at high fibre loading causing poor bonding of fibres. Similarly, the flexural strengths of the composites increased with fibre weight fraction. For instance, flexural strengths increased by 15.28%, 8.19%, 9.45% and 3.78% as fibre weight fraction increased from 30-40wt.%, 40-45wt.%, 45-50wt.% and 50-60wt.% respectively to attain maximum flexural strength of 27.16 MPa at 60wt.%. This observation is congruent with previous study [8] and can be explained by increased fibre loading thus increasing the ability of sisal fibres to resist applied bending forces. Also, the compressive strengths increased by 17.69%, 18.08%, 8.17% and 3.95% as fibre weight fraction increased from 30-40wt.%, 40-45wt.%, 45-50wt.% and 50-60wt.% respectively to attain maximum compressive strength of 23.94 MPa at 60wt.%. These findings are consistent with previous study [9] and may be attributed to improved fibre-matrix interfacial adhesion as well as absence of voids at the fibre-matrix interface thus the composites are able to withstand higher applied compressive loads.

- *Effect of fibre weight fraction on the tensile, flexural and compressive moduli of the composites*

Fig. 2 shows the effect of fibre weight fraction on tensile, flexural and tensile moduli of the composites. The results showed an increase in the tensile, flexural and compressive moduli of the composites with increase fibre weight fraction.

Figure 2: Effect of fibre weight fraction on tensile, flexural and compressive moduli of the composites

The tensile moduli of the composites increased by 37.21%, 11.86% and 42.42% as fibre loading increased from 30-40wt.%, 40-45wt.% and 45-50wt.% respectively. This observation is congruent with previous study [10] and may be attributed to increase in the amount of load-bearing elements, fibres, making the composites stiffer However, the tensile modulus reduced by 9.36% as fibre weight fraction increased from 50-60wt.% due to poor wettability of fibres by the matrix at higher fibre loading making the composite less stiff to withstand applied tensile loads. The compressive moduli of the composites increased by 5.73%, 16.26%, 6.36% and 15.54% as fibre weight fraction increased from 30-40wt.%, 40-45wt.%, 45-50wt.% and 50-60wt.% respectively. Also, the flexural moduli increased by 8.61%, 17.62%, 5.99% and 8.13% as fibre weight fraction increased from 30-40wt.%, 40-45wt.%, 45-50wt.% and 50-60wt.% respectively. The observed trend of increased flexural and compressive moduli with increase in fibre loading has been reported previously [11] and may be due to high dispersion of fibres in the matrix. This indicates enhancement in stiffness of the composites as a result of incorporation of more fibres in the composites.

The study further observed that the flexural moduli results were comparatively lower than the corresponding tensile moduli. The variations between tensile and flexural moduli can be explained by different types of stresses during testing. During tensile testing, the stresses are uniformly distributed throughout the cross sectional area of the specimen while in flexural testing the flexure stresses vary from zero in the middle to maximum in the bottom (tensile) and top (compressive) surfaces of the test specimen [12].

3.3 *Effect of fibre weight fraction on the impact strengths of the composites*

Fig. 3 shows the effect of fibre weight fraction on impact strengths of the composites.

Figure 3: Effect of fibre weight fraction on impact strengths of the composites

The impact strengths increased by 18.95% and 15.51% as fibre weight fraction increased from 30-40wt.% and 40-45wt.% respectively to attain maximum impact strength of 24.58 KJ/m^2 at 45wt.%. However, the impact strengths decreased by 7.45% and 19.03% as fibre weight fraction increased from 45-50wt.% and 50-60wt.% respectively. This trend of increasing impact followed by subsequent decline has been reported previously [13] whereby an increase in strength with fibre loading can be attributed to the increase in fibre content as well as increase in compressive pressure thus eliminating void contents in the composites while decrease can be explained by insufficient fibre-matrix interface bond hence the composites cannot withstand high impact loads.

IV. CONCLUSION

The effects of fibre weight fraction on mechanical properties of woven sisal fabric reinforced epoxy composites were investigated in the current study and the following conclusions drawn:

- Tensile strength increased with fibre weight fraction from 30% to 50%Vwf. This can be explained by increased amount of load bearing elements, fibres, in the composites as well as excellent fibre-matrix interfacial adhesion that ensure good stress transfer from the matrix to the fibres. However, as the fibre weight fraction increased from 50-60% fibre loading, there was reduction in tensile strength due to possible poor bonding of the fibres by the matrix as a result of reduced wettability.

- The flexural strength increased with increase in fibre weight fraction from 30% to 60%. This observation can be attributed to increased fibre content in the composite thus increasing the ability of sisal fibres to resist applied bending loads.
- The impact strength increased with fibre weight fraction up to 45%Vwf due to increase in fibre content as well as increase in compressive pressure thus eliminating void contents in the composites. However, the impact strength decreased as fibre weight fraction increased from 45% to 60% fibre loading due to insufficient fibre-matrix interface bond hence the composites could not withstand high impact loads.
- The compressive strength increased as fibre loading increased from 30% to 60%Vwf. This can be attributed to improved fibre-matrix interfacial adhesion as well as absence of voids at the fibre-matrix interface thus the composites are able to withstand higher applied compressive loads.

ACKNOWLEDGEMENTS

The authors are grateful to the National Commission for Science, Technology and Innovation (NACOSTI), Kenya for the financial support in carrying out this research work.

REFERENCES

[1]. Goulart S.A.S., Oliveira T.A., Teixeira A., Mileo P.C., Mulinari D.R., Mechanical behaviour of polypropylene reinforced palm fibers composites, Procedia Engineering; 10, 2011:2034-2039.
[2]. Dam, J. E. Environmental benefits of natural fibre production and use: In Proceedings of the Symposium on Natural Fibres, 2009.
[3]. Food and Agricultural commodities production/Countries by commodity; fao.org. FAOSTAT. Retrieved 29 May 2016, 2016.
[4]. Thatayaone Phologolo, Chongwen Yu, Josphat Igadwa Mwasiagi, Nobert Muya and Zheng Fan Li, Production and Characterization of Kenyan Sisal, Asian Journal of Textile, 2(2), 2012, 17-25. DOI: 10.3923/ajt.2012.17.25
[5]. Joseph, P. V., Joseph, K. and Thomas, S., The effect of processing variables on the physical and mechanical properties of short sisal fibre reinforced polypropylene composites. Composites Science and Technology, Oxford, 1999.
[6]. Fávaro, S. L., Ganzerli, T. A., de Carvalho Neto, A. G. V., da Silva, O. R. R. F., and Radovanovic, E., Chemical, morphological and mechanical analysis of sisal fibre-reinforced recycled high-density polyethylene composites. eXPRESS Polymer Letters Vol.4, No.8, 2010, 465–473; Available online at www.expresspolymlett.com DOI: 10.3144/expresspolymlett.2010.59.
[7]. Joseph, K., Thomas, S. and Pavithran, C.., Effect of surface treatments on the tensile properties of short sisal fibre –LDPE composites. Polymer, Oxford, v.37, p.23. 1996b.
[8]. Ghani, M. A. A., Salleh, Z., Hyie, K. M., Berhan, M. N., Taib, Y. M. D. and Bakri M. A., Mechanical properties of kenaf/fibreglass polyester hybrid composite, Procedia Eng; 41, 2012, 1654–9.
[9]. Sunil, K. R. S. and Akbar H. S. P., Development and Testing of Natural Fibre Reinforced Composites with Polyester Resin.” International Journal of Engineering Sciences & Research Technology, 2(10), 2013, 2701-2706.
[10]. Wambua, P., Ivens, J. and Verpoest, I.., Natural fibres: can they replace glass in fibre reinforced plastics? Composites Science and Technology, 63, 2003, p. 1259-1264.
[11]. [11]. Ramanaiah, K., Ratna P. A. V. and Hema C. R., Effect of Fibre Loading On Mechanical Properties Of Borassus Seed Shoot Fibre Reinforced Polyester composites, J. Mater. Environ. Sci. 3 (3), 2012, 374-378 ISSN : 2028-2508.
[12]. Folkes, M. Short fibre reinforced thermoplastics. Herts: John Wiley & Sons Ltd.; 1985. .
[13]. Zhong, J. B., Lv, J. and Wei, C.., Mechanical properties of sisal fibre reinforced urea formaldehyde resin composites.” eXPRESS Polymer Letters Vol.1, No.10; 2007, 681–687 Available online at: ww.expresspolymlett.com DOI: 10.3144/expresspolymlett.2007.93

Dennis O. Bichang’a Effect of Fibre Weight Fraction on Mechanical Properties of Woven Sisal Fabric Reinforced Epoxy Composites.” International Journal of Engineering Science Invention(IJESI), vol. 6, no. 11, 2017, pp. 72-75.