ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

DEVELOPMENT OF A FIBRE GLASS/SISAL FIBRE HYBRID COMPOSITE FOR USE AS A CROSSARM IN ELECTRICITY DISTRIBUTION NETWORK

NKOMO Nkosilathi[1], NDLOVU Lloyd[2], MUJENA Claytos[3]

[1,2, 3] National University of Science and Technology, Faculty of Engineering, Department of Fibre and Polymer Materials Engineering, Cnr Gwanda Road, Cecil Avenue, Ascot, Bulawayo, Zimbabwe

Corresponding author: Nkomo Nkosilathi, nkosilathi.nkomo@nust.ac.zw

Abstract: *Crossarms are one of the most important components in the electricity distribution sector. These are beams mounted on a utility pole which takes up load from the transmission wires and transfers it to the pole. Wooden crossarms which are mainly used but are prone to insect attacks and are susceptible to bio-deterioration. This study is focused on the development of a composite for potential use in the electricity distribution sector as a crossarm. The composite was fabricated using hand lay-up technique. The mechanical and electrical properties of the hybrid fiberglass/sisal fiber reinforced polyester were investigated. The results showed the highest tensile strength of 171.16 MPa. For flexural strength, the highest strength was 281.32 MPa. The highest compressive strength of 189.4 MPa was recorded. The insulation resistance was found to increase with the increase in fiberglass content. The study concludes that the hybrid sisal/fiberglass reinforced polyester composite crossarm has the potential to offer significant advantages over traditional crossarms in terms of performance, cost, and environmental impact. Futher studies are needed on aging performance of the composite and full-scale testing before commercial applications.*

Key words: *composite, electrical properties, fibreglass, mechanical properties, sisal fibre*

1. INTRODUCTION

Electric power is distributed through transmission lines that are supported by pylons and utility poles [1]. The supporting structures used for overhead transmission line conductors, such as poles and towers, are called the transmission line supports as shown in Fig 1. The line supports used for the distribution of electrical power can be made from wood, steel or composites [2]. The type of supporting structure used depends on factors such as the location of the line, importance of the line, desired lifetime of the line, money available for initial investment, cost of maintenance, and availability of material [3]. Wooden supporting systems have been used favorably for the support of electricity catenary wires because of their availability, low cost, insulating properties and ease of production [4]. The cross arms are mounted on a utility pole which takes up load from the transmission wires and transfers it to the pole. The cross arms also help to protect the conductors by providing support and security [5]. Wooden crossarms are prone to be attacked by insects which will eventually lead to their failure. Failure of crossarms in transmission network tends to disrupt electrical supply to end-users, and additional maintenance cost [6]. The wooden poles are treated with preservatives to help them last longer and keep bugs away.

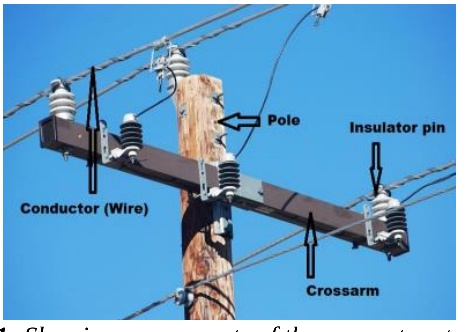

Fig. 1*: Showing components of the support system[7]*

Unfortunately, these preservatives contain dangerous chemicals such as pentachlorophenol that is harmful to humans, animals and the environment [8]. Furthermore, when wooden cross arms become compromised, there is small and sustained current flow leakage along the surface of the insulator and thereafter into the wood itself [9]. This may eventually lead to pole top fires. The fire can easily spread since many of the transmission lines traverse vast rural land and if this fire is not discovered timeously, it can cause breakage of the relevant cross arm or the pole itself. Therefore, there is a need to engineer a resistant and durable alternative. This study seeks to develop cross arms that will be able to last longer and have sufficient mechanical and resistance to electrical conductivity as required in the usage.

2. RESEARCH METHODOLOGY

2.1 Raw Materials

The study made use of glass fibre and sisal as the reinforcement materials in the composite and polyester resin NC901.The sisal fibres were treated with a 2% solution of NaOH for 1 hr. The fibers were then washed thoroughly with water to remove the excess of NaOH sticking to the fibers.

2.3 Fabrication of the composite material

The composite was fabricated using hand lay up technique. The experimental design followed in the study is as shown in table 1.

2.4 Characterization of the developed composite

Mechanical and electrical tests were carried out on the composite as outlined in the subsequent sections.

Table 1 – *Composite Experimental Design*

Number	Sisal fiber (%)	Fiberglass (%)
1[S20/G10]	20	10
2 [S18/G12]	18	12
3 [S16/G14]	16	14
4 [S14/G16]	14	16
5 [S12/G18]	12	18

2.4.1 Tensile Strength

A Universal testing machine (Testometric 500) was used to ascertain tensile strength as well as elongation at break. The specimens were prepared according to ASTM D3039. The tensile strength was determined at 2 mm/min crosshead-speed.

2.4.2 Compressive strength

The compressive strength was tested using a Universal testing machine (UTM) according to ASTM D3410.

2.4.3 Flexural strength

The flexural strength was tested according to ASTM D790 using a UTM machine. A three-point flexural test was carried out to find the flexural strength of the composite.

2.4.4 Insulation resistance

Insulation resistance testing was done to measure the resistance of the composite crossarm to the flow of electrical current. This test was conducted according to ASTM D257. The specimens were subjected to a voltage of 5 KV on a High Voltage Insulation Tester for a minute and the resistance was recorded.

3. RESULTS AND DISCUSSIONS

3.1 Tensile test results

Fig 3 shows the tensile properties of the developed composites.

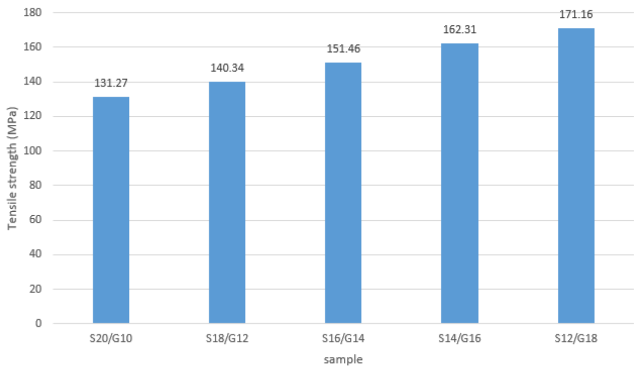

Fig. 3*: Showing the variation in tensile strength for different samples*

Sample S12/G18 with the least amount of sisal fibers had the highest tensile strength of 171.16 MPa. Addition of 2% fiberglass for sample 2 while maintaining the fiber volume fraction increased the tensile strength by 5%. It is seen from fig 3 that increase in fiberglass content considerably increases the tensile strength of the composite. This observation is consistent with study by [10] who showed a similar trend for green hybrid sisal and glass fiber composites. This may be attributed to the fact that sisal fibers carry less load when compared to glass fibers. Sample S20/G10 with a higher percentage of sisal fibers compared to fiberglass had the least tensile strength of 131.27 MPa. Another reason for higher tensile properties of hybrid composites may be due to higher percentage elongation of glass fibers as compared to sisal fibers as also observed by [10].

3.2 Compressive test results

Fig 4 shows the compressive strength of the composites according to the experimental design.

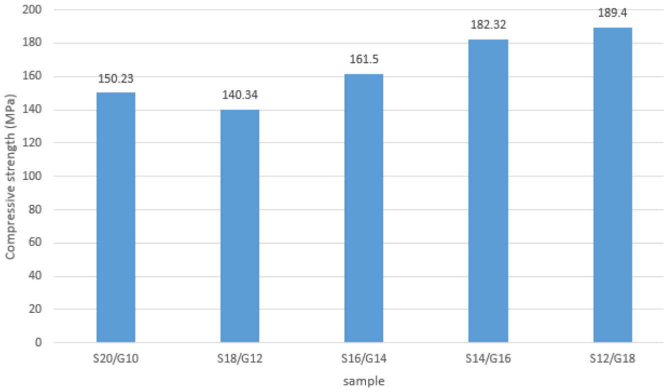

***Fig.** Error! No text of specified style in document.: Showing composite compressive strength*

A linear slight in compressive strength is observed with the increase in fiberglass content except for S18/G12. This agrees with the study done by [11] on the mechanical characterization of glass/sisal fiber reinforced composite. Sample S18/G12 has the least compressive strength. This could be due to the greater likelihood of fiber–fiber contact occurring which reduces the stress transfer ability of the composite. The maximum compressive strength of 189.4 MPa was obtained with sample S12/G18 which had higher fiberglass content due to the higher stiffness and strength of the glass fibers.

3.3 Flexural test results

Figure 5 shows the composite flexural strength.

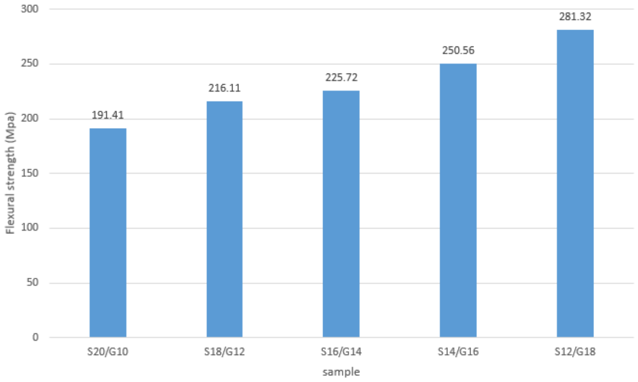

Fig. 5*: Showing the variation in flexural strength for the different samples*

Fig 5 shows an increase in flexural strength with increasing fiberglass content with sample S12/G18 having a maximum flexural strength of 281.2 MPa. This is an expected consequence of the better glass adhesion to polyester in comparison to the sisal adhesion and a consequently higher allowable degree of stress transfer to the fibers during loading. Sample S20/G10 has the least flexural strength of 191.41 MPa because it has the highest sisal fiber content. The results obtained are consistent with study by [12].

3.4 Insulation resistance test results

The results from the insulation resistance test are as shown in Fig 5.

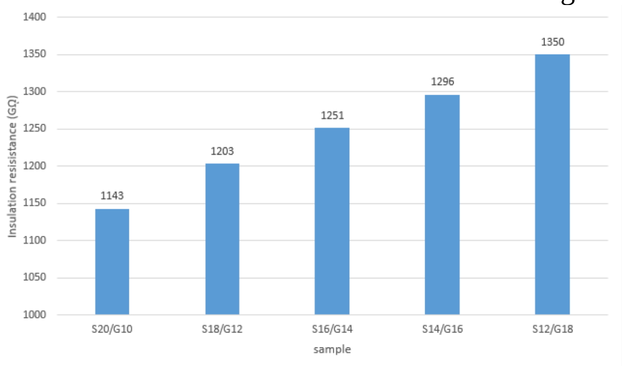

Fig 6: *Showing the variation in insulation resistance*

Fig 6 shows a linear increase in insulation resistance with an increase in fiberglass content. S12/G18 which has 18% fiberglass content had the highest resistance of 1350 GΩ and S20/G10 had the least resistance of 1143 GΩ. Addition of glass fibers improved resistivity of the composites. This is because the network of insulating fiberglass becomes denser, making it more difficult for electrical current to flow through the material. This is consistent with [13] who observed higher insulation resistance values of fiberglass reinforced crossarms. The higher insulation resistance values can also be attributed to the alkali treatment of the sisal fibers. The least resistance of S20/G10 can be due to higher sisal fiber content. As the proportion of sisal fibers increases, the orientation and alignment of the fibers can become more random, reducing the overall electrical strength of the composite. This can lead to a decrease in insulation resistance, as the material becomes more susceptible to electrical breakdown. The same effect was also reported by [14]. However, the developed composites showed higher insulation resistance values when compared to wood which was reported to be around 1400 KΩ by [15] which makes them a better alternative in the electricity distribution sector.

5. CONCLUSIONS

The main conclusions reached during this study are:

- Sisal/fiberglass reinforced polyester composites show potential as a sustainable alternative material for electrical crossarms due to their good mechanical properties, low cost and environmental friendliness.
- Hybridizing sisal and fiberglass fibers in the composite utilized the benefits of both while overcoming their individual limitations. The reinforcement formed a synergistic reinforcement system.
- The composites showed very high insulation resistance with S12/G18 which has 18% fiberglass content having the highest resistance of 1350 GΩ. When compared to wood the resistance makes them a better alternative in the electricity distribution sector.

ACKNOWLEDGEMENTS

This research was supported by the National University of Science and Technology.

REFERENCES

[1] E. Marlés-Sáenz, E. Gómez-Luna, J. M. Guerrero, and J. C. Vasquez, "Analysis of Impacts in Electric Power Grids Due to the Integration of Distributed Energy Resources," *Energies,* vol. 18, p. 745, 2025.

[2] H. Gao, Y. Sun, J. Jian, Y. Dong, and H. Liu, "Study on mechanical properties and application in communication pole line engineering of glass fiber reinforced polyurethane composites (GFRP)," *Case Studies in Construction Materials,* vol. 18, p. e01942, 2023.

[3] T. Kishore and S. K. Singal, "Optimal economic planning of power transmission lines: A review," *Renewable and Sustainable Energy Reviews,* vol. 39, pp. 949-974, 2014.

[4] A. A. Latif, M. R. Ishak, M. R. Razman, N. Yidris, M. Y. Mohd Zuhri, M. A. M. Rizal, *et al.*, "Experimental and numerical analysis of pGFRP and wood cross-arm in latticed tower: a comprehensive study of mechanical deformation and flexural creep," *Scientific Reports,* vol. 15, p. 1432, 2025.

[5] M. Ahsan, M. N. R. B. Baharom, Z. Zainal, L. H. Mahmod, I. Ullah, M. F. M. Yousof, *et al.*, "Historical review of advancements in insulated cross-arm technology," *Energies,* vol. 15, p. 8221, 2022.

[6] P. Rajeev, S. Bandara, E. Gad, and J. Shan, "Structural assessment techniques for in-service crossarms in power distribution Networks," *Infrastructures,* vol. 7, p. 94, 2022.

[7] Y. M. Degu, "Enhancing productivity through work study-A case of electric power pole cross arm fabrication," *Heliyon,* vol. 10, 2024.

[8] E. CU and K. K, "Pentachlorophenol and its effect on different environmental matrices: the need for an alternative wood preservative," *Sustainable Earth Reviews,* vol. 7, p. 22, 2024.

[9] K. L. Wong, S. Pathak, and X. Yu, "Aging effect on leakage current flow in wooden poles," *IEEE Transactions on Dielectrics and Electrical Insulation,* vol. 16, pp. 133-138, 2009.

[10] M. Gupta and V. Deep, "Effect of water absorption and stacking sequences on the properties of hybrid sisal/glass fibre reinforced polyester composite," *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications,* vol. 233, pp. 2045-2056, 2019.

[11] G. M. Kumar and A. Vasanthanathan, "Investigation of mechanical and interfacial characterization of hybrid sisal/glass fiber reinforced composites," *Materials Today: Proceedings,* vol. 47, pp. 7041-7044, 2021.

[12] R. B. Baloyi, S. Ncube, M. Moyo, L. Nkiwane, and P. Dzingai, "Analysis of the properties of a glass/sisal/polyester composite," *Scientific Reports,* vol. 11, p. 361, 2021.

[13] S. Grzybowski and T. Disyadej, "Electrical performance of fiberglass crossarm in distribution and transmission lines," in *2008 IEEE/PES Transmission and Distribution Conference and Exposition,* 2008, pp. 1-5.

[14] N. Nayak, H. Reddappa, G. Kalagi, and V. Bhat, "Electrical insulating properties of natural fibre reinforced polymer composites; a review," *Int J Eng Res,* vol. 6, pp. 165-169, 2017.

[15] M. H. Bollen and S. K. Rönnberg, "Hosting capacity of the power grid for renewable electricity production and new large consumption equipment," *Energies,* vol. 10, p. 1325, 2017.