

EFFECT OF FIBRE LOADING AND CONCENTRATION OF NaOH USED FOR SURFACE MODIFICATION OF FIBRE ON MECHANICAL PROPERTIES OF EPOXY/SISAL FIBRE COMPOSITES

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ABSTRACT

The present work comprises of fabrication and analysis of epoxy composites reinforced with short sisal fibre. The effect of loading of sisal fibre on the various mechanical properties are investigated. Apart from that the present work also comprises studying the effect of the concentration of NaOH used for the surface modification of sisal fibre on the various mechanical properties. The properties under investigation are tensile strength, flexural strength and compressive strength. The composites are fabricated using the hand lay-up method and the fibre loading varies from 2.5 wt. % to 10 wt. %. The concentration of NaOH selected for modifying the surface of sisal fibre is 2 moles, 4 moles and 6 moles. The major advantage of modifying the surface of natural fibre is that it improves the adhesion between fibre and matrix along with improving the mechanical properties of the material. From the experimentation, it is observed that the inclusion of sisal fibre improves the various mechanical properties of the composites under investigation. From the analysis it is seen that composite with surface modified sisal fiber yield better results and further fiber treated with 2 mole NaOH concentration is superior among their counterpart.

1. INTRODUCTION

Composite materials are being established to improve and adapt outdated products and present fresh products in a sustainable and answerable way [1]. Polymer composite materials derived from some sort of natural resources are successfully replacing the non-biodegradable composite material and even various conventional materials. The reasons behind this are the multiple benefits provided by them which include its light weight, low cost, ease and cheap manufacturing, high flexibility, high specific strength, biodegradable and environmental friendly in nature [2]. Apart from this, natural fibers do not generate any harmful gases during its processing. But the development of high performance composite material derived from natural resources is an ambitious goal which is presently of interest among the scientific community all across the world. The main concern with natural fibers is their hydrophilic nature as it restricts them to be the first choice as reinforcement with polymeric resin. Because of this hydrophilic nature, the composite fabricated had high water absorption rate which has several drawbacks like poor matrix-fiber interfacial adhesion, improper distribution of fiber within polymeric matrix and low stress transfer efficiency [3]. A significant work is in progress to overcome this problem by modifying the surface of the fiber with chemical treatment process. It has been observed that there is tremendous enhancement in various properties of the natural fiber composite material developed by this method [4, 5].

Surface modification of natural fibers results improved adhesion between matrix and fiber and simultaneously reduce the hydrophilic nature of the fiber. Among them the most widely used treatment methods are alkaline treatment as it is simple, economic and effective. Proper alkalization reduces the diameter of fiber as well and with reduced diameter, for given weight fraction, surface area of fiber increases which provide better adhesion with continuous phase [6]. Saravanakumaar et al. [7] reinforce alkali treated kenaf fiber in polypropylene matrix and compared the mechanical properties of composite with and without fiber treated composite. They reported to find significant improvement in mechanical properties when treated fiber was used. In more recent work, Asumani et al. [8] treated papaya fibers with NaOH aqueous solution at room temperature and varied the time of treatment. In their study they concluded that treatment time also governs the mechanical property of the developed material.

Among the various natural fibers, sisal fiber is considered to be the best option because of multiple benefits. In this regard, the work concentrates on modifying the surface of the sisal fiber with aqueous solution of NaOH for fabrication of polymer composites with epoxy as base matrix. The main aim of the work is to present the influence of fiber modification on response to mechanical loading for the fabricated samples. Also the work consists of optimizing the concentration of NaOH to be used with sisal fiber for providing better results as under and over treatment both are undesirable. The different mechanical properties under consideration are tensile strength and extension, flexural strength and compressive strength.

2. MATERIAL AND METHODS

Thermoset epoxy resin LY 556 in combination with triethylene tetramine HY951 is selected as the continuous phase in the present work. Epoxy has a low density of 1.13 gm/cm^3 . It is readily available at low cost and processing is also quite easy which make this polymer suitable for present investigation. Among the various natural fibres, sisal fibre is the most promising to be used as reinforcement in polymer composites as it is relatively inexpensive and commercially available. In present investigation, sisal fibre is used in its short form. An approx. 4 mm length of sisal fibre is used for composite fabrication. A NaOH flake is supplied by Rankem Corporation Limited; New Delhi, India is used for modification of fibre surface in present work. In the present investigation epoxy-based composites are fabricated by simple hand lay-up technique. Sisal fibres are treated with NaOH solution before processing. The concentration level of NaOH considered in the study is 2 mole, 4 mole and 6 mole concentration. Epoxy composites with both treated and non-treated sisal fibres are prepared at four different fibres loading i.e. 2.5 wt. %, 5 wt. %, 7.5 wt. % and 10 wt. %. In total sixteen sets of composites are fabricated to perform the present study. Mechanical characterization of the samples includes response of material on tensile loading, flexural loading, compressive loading and indentation. All the experimentation under consideration are conducted in computerized Instron 3382 Universal testing machine. Tensile tests were performed in accordance with ASTM D638 procedure. The compression test is performed as per ASTM D695 standard. The flexural test was carried out as per ASTM D2344-84 standard in the same universal testing machine.

3. RESULTS AND DISCUSSION

Tensile Strength- The ultimate tensile strength of all sets of material developed in the present work is presented in figure 1. The figure shows the variation in tensile strength of the material as a function of fibre content and concentration of NaOH used for fibre treatment. It is clear that the inclusion of fibres in small fractions i.e. 2.5 wt. % reduces the tensile strength drastically irrespective of untreated or treated fibres. Later, when the content of fibre increases, an increase in the value of tensile strength is noticed. The trend is similar for all sets of composites under investigation. The ultimate tensile strength of neat epoxy is measured to be 27 MPa. With the addition of raw sisal fibre, the tensile strength of composites reduces to 16.4 MPa for a combination of epoxy with 2.5 wt. % raw sisal fibre. With the further addition of sisal fibre, tensile strength increases with fibre content and maximum tensile strength of 24.5 MPa is obtained with 10 wt. % of sisal fibre. Further, it is observed that surface modification of sisal fibre using an aqueous solution of NaOH results in an improvement in the tensile strength of the fabricated composites. Tensile strength also varies with the concentration of NaOH used for the alkaline treatment of fibre. Fibres treated with 2 wt. % NaOH aqueous solution delivers better results irrespective of the content of fibre as compared to their counterparts. Maximum tensile strength of 36.5 MPa is obtained when a 2-mole concentration of NaOH treated 10 wt. % sisal fibre is added in epoxy. The improvement is around 62 % over neat epoxy. It is observed that when the concentration of NaOH for treatment increases, a reduction in the value of tensile strength is obtained. It can be explained as when the concentration of NaOH is low i.e. 2 wt. %, then the surface material present over sisal fibre dissolves completely. Further, excessive fibre treatment partially removed the cellulose from the surface of the fibre. With the removal of cellulose, the mechanical properties of the single sisal fibre reduce which reduces the overall strength of the material. Hence, limited concentration treatment of sisal fibre is suggested for improving the tensile strength of the composites.

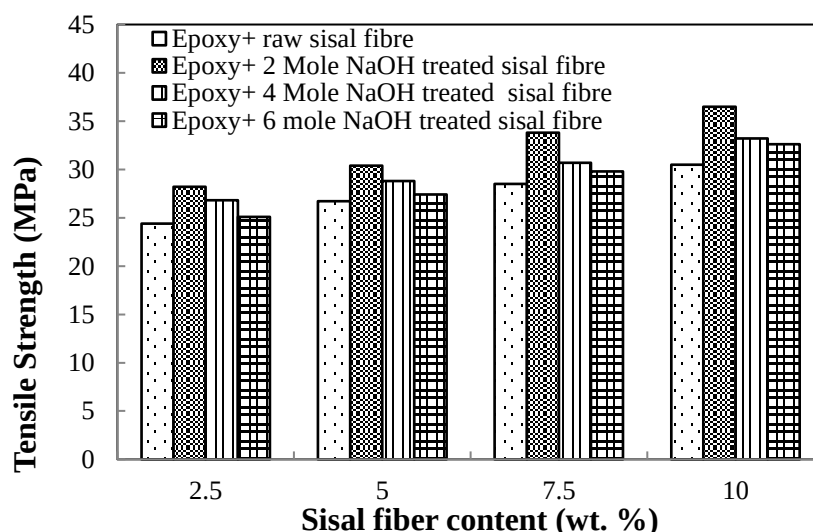


Figure 1. Ultimate tensile strength of epoxy/sisal fibre composites with treated and untreated fibres as a function of the fibre content

Compressive Strength- The variation in compressive strength of epoxy composites filled with varying content of sisal fibre is presented in Figure 2. From the figure, it is clear that the compressive strength of the material increases with an increase in fibre content. The increasing trend in the value of compressive strength with an increase in fibre content is for all sets of composites irrespective of treated or untreated fibre. The Compressive strength of neat epoxy is measured to be 76.5 MPa. When raw sisal fibre is incorporated into it, the compressive strength increases to 79.7 MPa with 2.5 wt. % of sisal fibre. This increment is continuous and compressive strength increases to 88.8 MPa when 10 wt. % of sisal fibres are added. This is an increment of 16.07 %. Similarly, when 10 wt. % of treated fibres are incorporated in epoxy resin, the compressive strength increases to 102.5 MPa, 98.9 MPa and 92.4 MPa for 2 moles, 4 moles and 6 moles NaOH concentrations respectively. The increment is 33.98 %, 29.28 % and 20.78 % for 2 moles, 4 moles and 6 moles NaOH concentration treated fibres respectively. The compressive strength of the composite materials increases with fibre loading because the inclusion of sisal fibres provides rigidity to the material. The composites prepared with 2 moles treated sisal fibres obtain a higher compressive strength.

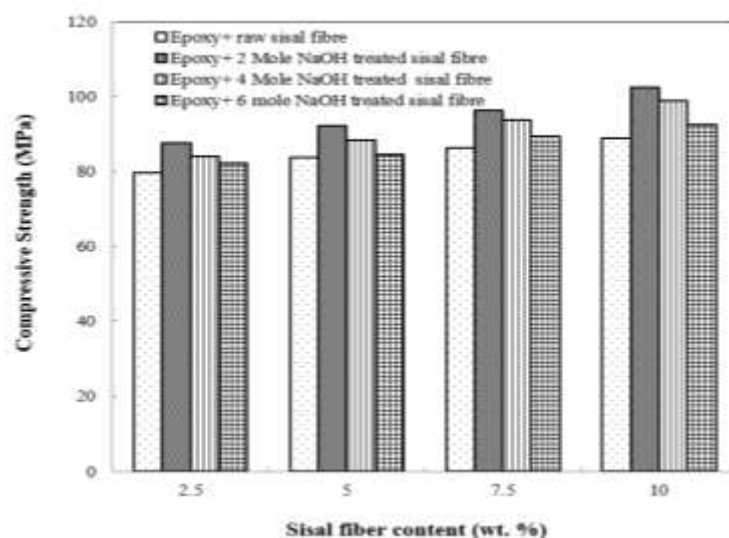


Figure 2 Compressive strength of epoxy/sisal fibre composites with treated and untreated fibres as a function of the fibre content

Flexural Strength- The flexural strength of sisal fibre-reinforced epoxy composites with and without surface treatment is shown in figure 3. The flexural strength of neat epoxy is 27.3 MPa. When raw sisal fibres are added to epoxy resin, the flexural strength of composites increases when a small quantity of fibres is added. When 2.5 wt. % of fibres are added, and flexural strength increases to 28.1 MPa. With the further addition of raw sisal fibre, flexural strength increases with the raw sisal fibre content. When 10 wt. % of raw sisal fibres are added, and flexural strength reduces to 31.9 MPa. When raw fibres are loaded, because of low interfacial adhesion and improper fibre wetting the increment in the value of flexural strength is low. When treated sisal fibres are incorporated in epoxy resin, the flexural strength of the composites increases appreciably and the trends continue as the fibre content increases.

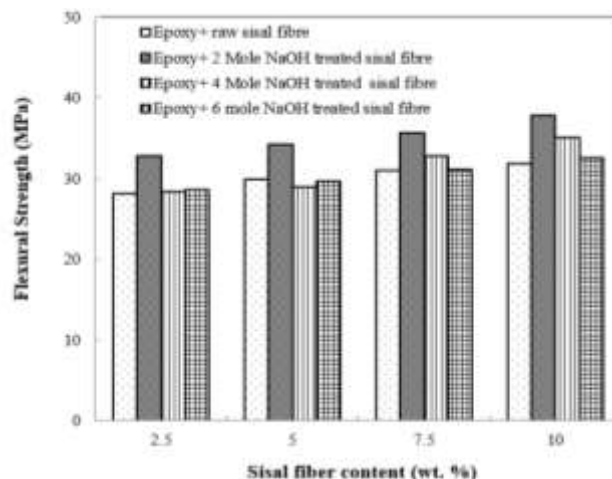


Figure 3 Flexural strength of epoxy/sisal fibre composites with treated and untreated fibres as a function of the fibre content

A similar trend is obtained with all treated fibres irrespective of the concentration used. The enhancement in flexural strength with treated fibre is due to strong fibre-matrix interfacial bonding. With this, the material withstands a high bending load as compared to its counterpart. Further, sisal fibre treated with 2 moles NaOH concentration yields better results as compared to other similar sets. It is again due to damage of fibre when over-treatment occurs. Maximum flexural strength of 37.8 MPa is achieved with 2 mole NaOH treated fibre at 10 wt. % of sisal fibres. An appreciable increment of 38.5 % is observed. Again, when 4 mole NaOH treated fibre is used, 35.1 MPa of flexural strength is obtained and when 6 moles NaOH treated fibre is used, 32.5 MPa of flexural strength is noticed. This is an increment of 28.5 % and 19.2 % respectively.

4. CONCLUSION

The present investigation leads to the conclusions that the modification of surface of sisal fiber using aqueous solution of NaOH improves the various mechanical properties of composite and best result is obtained when fiber surface are modified with 2 mole NaOH aqueous solution. With the addition of sisal fibre, the tensile strength of composites increases as a function of fibre loading. Tensile strength also varies with NaOH concentration used for alkaline fibre treatment. Fibres treated with 2 wt. % NaOH aqueous solution delivers better results irrespective of the content of fibre as compared to their counterparts. Compressive strength of the material increases with an increase in fibre content. The increasing trend in the value of compressive strength with an increase in fibre content is for all sets of composites irrespective of treated or untreated fibre. Again, the composite prepared with 2 moles treated sisal fibre delivers better compressive strength as compared to their counterparts. When raw sisal fibres are added to the epoxy resin, the flexural strength of composites increases as a function of fibre loading. A similar trend is obtained when surface-modified sisal fibres are added to the epoxy matrix. Among all the fabricated samples, the composites prepared with 2 moles NaOH treated sisal fibre deliver maximum strength for a given fibre loading. The best result is obtained when fibre surfaces are modified with a 2 mole NaOH aqueous solution.

5. REFERENCES

- [1] Mitra B C 2014 Def. Sci. J. **64** 244-252.
- [2] Gupta M K and Srivastava R K 2015 Mater. Today Proc. **2** 2909-2917.
- [3] Mochane M J et al 2019 Express Polym. Lett. **13** 159-198.
- [4] Saba N et al 2016 Constr. Build. Mater. **124** 133-138.
- [5] Kiruthika A V 2017 J. Build. Eng. **9** 91-99.
- [6] Mwaikambo L Y and Ansell M P 2002 J. Appl. Polym. Sci. **84** 2222-2234.
- [7] Saravana kumar A et al 2018 Int. J. Polym. Anal. Charact. **23** 529-536.
- [8] Asumani et al 2012 Compos. Part A Appl. Sci. Manuf. **43** 1431-1440.