Effect of Alkali Treatment on Mechanical Properties of Non-woven Jute Fiber Reinforced Epoxy Composite

RajuAhammad, Md Arifuzzaman and Md Shariful Isalm
Faculty of Mechanical Engineering
Khulna University of Engineering & Technology
Khulna-9203, Bangladesh
rajuahammad@me.kuet.ac.bd, arif48@me.ket.ac.bd,
msislam@me.kuet.ac.bd

Abstract

Jute fiber-reinforced polymer matrix composites are highly desirable because they can offer sustainable alternatives to traditional materials. Researchers have been trying to improve the overall characteristics of these composites in different ways, alkali treatment is one of them. In this study, the effect of NaOH treatment on the mechanical characteristics of randomly distributed non-woven jute fiber-reinforced epoxy composites is investigated. The effects of various NaOH concentrations (0%, 5%, 10%, and 15%) on mechanical properties are investigated by experimentation. The composites were fabricated using hand layup followed by the compression molding method. The treatment of fibers using 5% NaOH solution showed a significant improvement in tensile strength, flexural strength, tensile modulus, flexural modulus, and energy absorption while maintaining a tolerable elongation at break. The treatment of fibers using higher NaOH concentration caused a decrease in tensile and flexural properties due to possible fiber damage during treatment. Fiber treatment using NaOH is found to be effective for the enhancement of mechanical properties of fiber-reinforced composites but care should be taken to optimize the concentration of NaOH used for fiber treatment.

Keywords
Jute fiber composite, Alkali treatment, Tensile properties, Flexural properties, Energy absorption.

1. Introduction
Fiber-reinforced composites have become a sustainable choice for industries that require lightweight but high-strength materials. These composites are made of a matrix material that encases and binds together a reinforcing phase made of high-strength fibers. The final composite's mechanical, thermal, and occasionally even electrical properties are improved due to the interaction between the matrix and fibers (Kurien et al., 2023). These composites can be tailored to meet the needs of particular applications. The use of natural fibers as reinforcement materials is a noteworthy approach in the field of fiber-reinforced composites. Natural fibers, which come from sources like plants and animals, provide advantages compared to synthetic fibers because of their biodegradability, low cost, and environment-friendly nature. They conform to the sustainability criteria because they are renewable, biodegradable, and frequently produce with less energy. Because of their innate biocompatibility, these fibers are also appropriate for applications where it is inevitable that they will come in contact with humans or other living things. Jute fiber stands out as a particularly attractive option for composite reinforcement among the variety of natural fibers because of their wide availability and low cost. Its broad cultivation and quick rate of growth make it a resource that can be collected periodically and is sustainable. Additionally, jute fibers have outstanding mechanical qualities, such as good tensile strength and modulus, which puts them on pace with various synthetic fibers. Jute fibers have many qualities that make them suitable for use in composite material reinforcing. For instance, their elongated, adaptable shape improves load distribution inside the composite matrix, leading to increased mechanical integrity (Ashraf et al., 2019). Jute fibers also naturally absorb and release moisture, which can help alleviate problems with humidity-induced degradation that are frequently found in composite materials. The hygroscopic characteristic of jute-reinforced composites may be used to improve their overall toughness (Cottrell et al., 2023).

Regardless of the inherent benefits that natural fibers have over their synthetic counterparts, it is noteworthy that the literature also highlights some limitations associated with natural fibers. For example, the tendency to absorb more water and less mechanical strength (Judawisastra et al., 2017; Nurazzi et al., 2018). The research landscape has seen the development of numerous tactics targeted at minimizing these limitations (Haque & Hasan, 2018; Jahan et al., 2020). Alkali treatment of the fiber has become a crucial modification technique in this context, denoting a proactive strategy to improve the mechanical properties of the resultant composites.

The increasing need for ecologically friendly technologies in engineering and sustainable materials is what motivated this investigation. The study's importance derives from its emphasis on using NaOH treatment to improve the mechanical characteristics of polymer composites reinforced with jute fiber. Since jute is a natural fabric, it is a sustainable and biodegradable substitute for non-renewable materials. Examining how treatment affects these composites offers important information about how precisely altering their surface might increase their durability and strength, which has significance for applications in sectors that demand high-performance materials. The overall goal of this research is to promote sustainability in engineering and manufacturing while mitigating the negative effects on the environment.

1.1 Objectives

In most of the literature, the jute/epoxy composites were made by using chopped fiber, woven bidirectional fiber, and woven unidirectional jute fiber. Limited studies were found regarding the usage of randomly distributed non-woven jute fabric mats. Therefore, in this present work, the effect of alkali treatment on the mechanical properties (tension and flexural) of randomly distributed non-woven jute fiber reinforced epoxy composites was investigated.

2. Literature Review

When jute fibers are subjected to the alkali treatment, their chemical and structural changes occur at the fiber surface (Kapatel, 2021). These changes include the elimination of contaminants, lignin, and hemicellulose, leading to a smoother surface of the fiber and increased wettability. These modifications make the jute fibers more receptive to epoxy matrix penetration and adherence (Islam et al., 2021). Alkali treatment also increases the surface area of the fiber, resulting in improved mechanical interlocking and stress transmission properties within the composite structure.

Behera et al. (2023) modified jute fibers by utilizing sodium hydroxide (SH), sodium carbonate (SC), and sodium hydrogen carbonate (SHC) to investigate the morphological, water absorption, mechanical, and tribological characteristics of jute fiber-reinforced epoxy composites (JFREC). The mechanical properties, including tensile strength, tensile modulus, and impact strength, exhibited notable enhancements for SH JFREC (38.08%, 30.56%, and 31.66%), SC JFREC (70.03%, 33.06%, and 41.30%), and SHC JFREC (24.69%, 8.88%, and 22.61%) in comparison to untreated JFREC. The findings also confirm that the chemical modification leading to improved fiber-matrix adhesion contributes to increased water absorption resistance and enhanced tribological properties in the chemically modified JFREC.

Sarker et al. (2022) investigated the use of sodium bicarbonate chemical treatment for jute fibers in natural fiber composites. In order to make composites, they used jute fibers treated with 5% and 10% sodium bicarbonate solutions reinforced with epoxy resin. Significant increases in tensile characteristics and interfacial adhesion were revealed by mechanical characterizations, which include single fiber tensile tests and flexural testing.

Karabulut et al. (2018) investigated how surface modification affects the mechanical characteristics of laminated composite plates reinforced with woven jute fiber mats. Surface modification of woven jute fabrics was achieved by soaking them for 15 days at room temperature in different concentrations (0%, 5%, 10%, and 15%) of NaOH solution. Laminated composite plates with epoxy, polyester, and vinyl ester matrices were subsequently made using modified woven jute fibers of six layers. The resultant composites have different mechanical qualities; woven jute polyester laminates have the lowest properties, and woven jute epoxy laminates have the highest. The mechanical properties of woven jute fabric-reinforced laminated composites were improved by the chemical treatment; the ideal concentration for improvement was 10% NaOH.

Effect of alkali treatment has been also used for other natural fibers. Rajeshkumar et al. (2021) studied the effect of sodium hydroxide treatment of concentrations 5%, 10%, 15%, and 20% on cellulosic fibers obtained from petioles of Phoenix sp. plants reinforced epoxy composites. It was investigated and optimized how various treatments affected the final composites' tensile, flexural, impact, and dynamic mechanical properties. Single fiber pull-out and morphological investigations verified that the treated fibers had better interfacial adhesion with the epoxy matrix. In comparison to untreated fiber composites, the treated fiber composites showed improved static and dynamic mechanical characteristics and fewer failure mechanisms, such as fiber pull-outs and fiber debonding. In particular, it was shown that composites made with fibers treated with 15% sodium hydroxide might be used to produce vehicle panels and other lightweight industrial items. Sodium hydroxide (NaOH) has the ability to eliminate non-cellulosic elements and contaminants, enhance the amount of amorphous cellulose, change cellulose I into cellulose II, and produce a larger surface area and porous volume. The interfacial bonding between the constituents of the composite is improved by these properties (Nagarajan et al., 2017). Natural fibers have been treated with NaOH by numerous researchers to improve the mechanical and viscoelastic properties of composite materials (Gunge et al., 2019; Negawo et al., 2019).

Singh et al. (2020) investigated the effect of alkali (NaOH) treatment on the mechanical properties of biodegradable bidirectional woven jute/epoxy composite. They found that the tensile strength, tensile modulus, flexural strength, and flexural modulus were increased when 5% NaOH treatment was used. Wang et al. (2019) investigated the effect of hot alkali treatment with five concentrations (2%, 4%, 6%, 8%, and 10%) for woven jute/epoxy composites. When compared to the corresponding properties of composites reinforced with untreated fabrics, the tensile strength, flexural strength, tensile modulus, and flexural modulus of the 6% NaOH-treated fabrics showed improvements of 37.5%, 72.3%, 23.2%, and 72.2%, respectively. The significant improvement in mechanical properties emphasizes how drastically the NaOH treatment changed the mechanical properties of the resulting composite materials.

In a separate study, Sinha and Panigrahi (2009) investigated the flexural properties of jute fiber/unsaturated-polyester resin composites treated with 5% alkali for varying durations (2 hours, 4 hours, and 6 hours) were examined. The results showed that the flexural strength of composites fabricated with fibers treated for 2 hours and 4 hours increased by approximately 3.16% and 9.5%, respectively, when compared to untreated jute fiber composites. Furthermore, in another study conducted by Boopalan et al. (2012), it was found that jute/epoxy composites treated with 20% alkali exhibited substantial improvements in both tensile strength (approximately 108%) and flexural strength (approximately 28%) in comparison to their untreated counterparts.

In a previous study carried out by Saha et al. (2010), the physio-chemical properties of jute fibers were investigated in response to various NaOH concentrations (from 0.5% to 18%), temperatures, and treatment times. The findings showed that the fibers' tensile strength increased by about 65% when they were submerged in a 0.5% NaOH solution for 30 minutes and then treated with a NaOH stream for another 30 minutes. Furthermore, a different study conducted by Roy et al. (2012) suggested that using a lower concentration (about 0.5 wt%) of alkali treatment for a longer period led to appreciable improvements in the tensile strength (about 82%) and elongation at break (about 45%) of jute fibers, while also decreasing their hydrophilicity by about 50.5%.

Mahesh et al. (2022) used 5%, 10%, and 15% NaOH solutions to modify the surface of woven jute fabric and made jute/epoxy composites. They found the optimal concentration of NaOH solution of 5% for better mechanical properties. Jute fiber composites reinforced with epoxy and polyester resins were assessed in a study by Gopinath et al. (2014). The length of the jute fiber was 5-6 mm. Jute fibers were treated with 5% and 10% NaOH. Notably, the outcomes showed that the epoxy composite outperformed the polyester composite in terms of mechanical properties. Additionally, the 5% treatment produced better tensile and flexural characteristics in the NaOH-treated jute composites than the 10% treatment.

To sum up, the literature review highlights the vital role of NaOH treatment in improving the mechanical characteristics of jute fiber composites, hence increasing their feasibility for various engineering uses. The results of the investigations consistently show a significant increase in modulus, flexural characteristics, and tensile strength, highlighting the groundbreaking effects of controlled surface alteration. Additionally, certain performance qualities can be achieved by the customization of treatment parameters such as time and concentration, which opens up a potential avenue for improvement. It is crucial to remember that many parameters, such as matrix compatibility, treatment conditions, and fiber type, may affect how effective the NaOH treatment is.

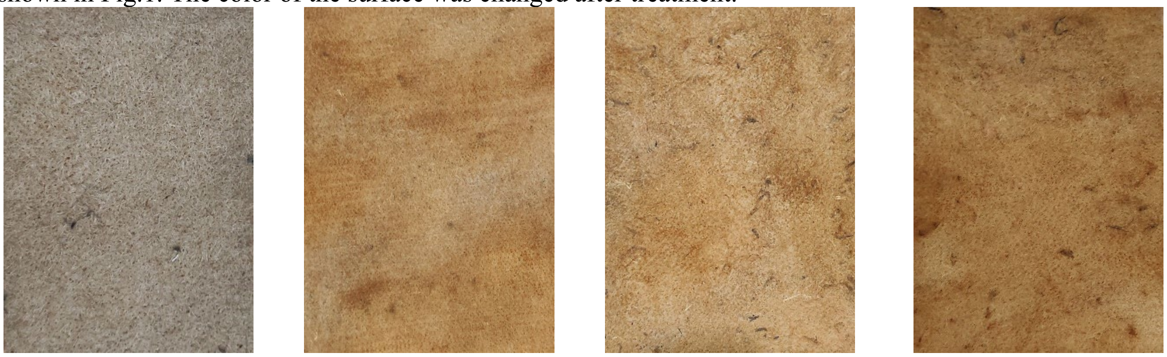
3. Methods

3.1 Materials

The epoxy resin and hardener (Brand name: Amazing Epoxy) were collected from the local market. The randomly distributed non-woven jute fiber mat was collected from Jute Textile Mills Ltd., Khulna, Bangladesh. A randomly distributed non-woven jute fiber mat is a sort of textile fabrication made of jute fibers that are randomly arranged rather than woven into a particular pattern as shown in Fig.1 (a). Depending on the intended use, these mats can have a range of densities, thicknesses, and fiber contents.

3.2 Fabric Treatment

At first, alkaline solutions with NaOH concentrations of 5%, 10%, and 15% were applied to jute fiber mats individually. To ensure uniform treatment conditions for all samples, the mats were submerged in the appropriate solutions for 2 hours. The mats were carefully rinsed in distilled water to remove any remaining alkaline material after the alkali treatment. To remove any remnants of the treatment solution and preserve the integrity of the fibers, a meticulous washing procedure was carried out. The cleaned jute fiber mats were then dried using sunlight. The additional moisture that accumulated throughout the treatment and washing phases was made easier to evaporate by being exposed to direct sunlight for approximately six hours. The solar drying process was critical for restoring the mats to optimal moisture content and ensuring consistency in the subsequent composite production steps. The appearance of untreated and treated jute fiber mats is shown in Fig.1. The color of the surface was changed after treatment.



(a) Untreated (b) 5% NaOH (c) 10% NaOH (d) 15% NaOH

Figure 1. Photographic view of (a) untreated and (b-d) treated jute fiber mats.

3.3 Composite Manufacturing

To ensure consistent quality and structural integrity, a rigorous and systematic process was followed during the manufacture of the composite. The epoxy matrix was first prepared before starting the composite fabrication. Epoxy resin was mixed with hardener at a 3:1 ratio according to the manufacturer's recommendation. A pre-fabricated silicone mold with dimensions of 250 mm×150 mm×12 mm was used for making the composites. The desired composite size was taken into consideration while the epoxy resin and hardener mixture were poured onto the mold. For manufacturing jute fiber reinforced composites, the hand layup followed by compression molding technique was adopted. A grooved roller was used to make sure the jute fiber mat was properly impregnated by resin mixture and the air bubble was removed. A glass plate was placed on top of the impregnated jute fabric and a 50 kg load was placed on top of the glass plate. After 48 hours of curing under pressure, the composite was carefully taken out of the silicone mold and cut to the required size according to the standards for testing.

3.4 Mechanical Testing

The tensile test was conducted on a universal testing machine (Shimadzu AGX 300 kN) at a crosshead speed of 5 mm/min by following ASTM standard D 3039. The dimension for the tensile testing specimen was 250 mm×15 mm×4 mm. The flexural test was conducted on the same machine at a crosshead speed of 2 mm/min by following the standard of ASTM D 790. The dimension for the flexural testing specimen was 80 mm×13.5 mm×4 mm. Four specimens of each category were tested at room temperature to ensure the reproducibility of the results.

4.0 Results and Discussion

4.1 Tensile Properties

The tensile strength of untreated non-woven jute/epoxy composite and those treated with various concentrations of sodium hydroxide is shown in Fig.2 (a). The error bars in the figure indicate the standard deviations. The tensile strength for the composite made of untreated jute mat was 23.65 MPa which improved noticeably after being treated with 5% NaOH, reaching a value of 29.92 MPa. Comparing the treated composite to the untreated composite indicates an about 26.53% improvement in tensile strength. The composite made with jute fabrics treated with 10% NaOH also showed a slightly higher tensile strength (i.e., 24.69 MPa) compared to untreated jute/epoxy composite. However, the composite made with jute fabric that was treated with 15% NaOH, the tensile strength decreased noticeably, falling to 21.75 MPa, 8.03% less than the untreated composite.

Tensile modulus measurements taken for the randomly distributed non-woven jute/epoxy composites at different NaOH treatment concentrations (5%, 10%, and 15%) in comparison to the untreated composite (0% NaOH) are shown in Fig.2 (b). The tensile modulus of the untreated composite was found to be 2.98 GPa. The tensile modulus increased when the jute fibers were treated with 5% NaOH, reaching a value of 4.51 GPa. This represents a remarkable 51.01% improvement when compared to the untreated composite. In contrast, increasing the concentration of NaOH for treatment resulted in a gradual reduction in tensile modulus similar to the tensile strength. After treatment with 10% NaOH, the tensile modulus was 3.17 GPa which is 6.71% greater than the untreated composite. Additionally, at 15% NaOH concentration, the tensile modulus is dropped to 2.63 GPa, representing an 11.94% decrease from the untreated composite.

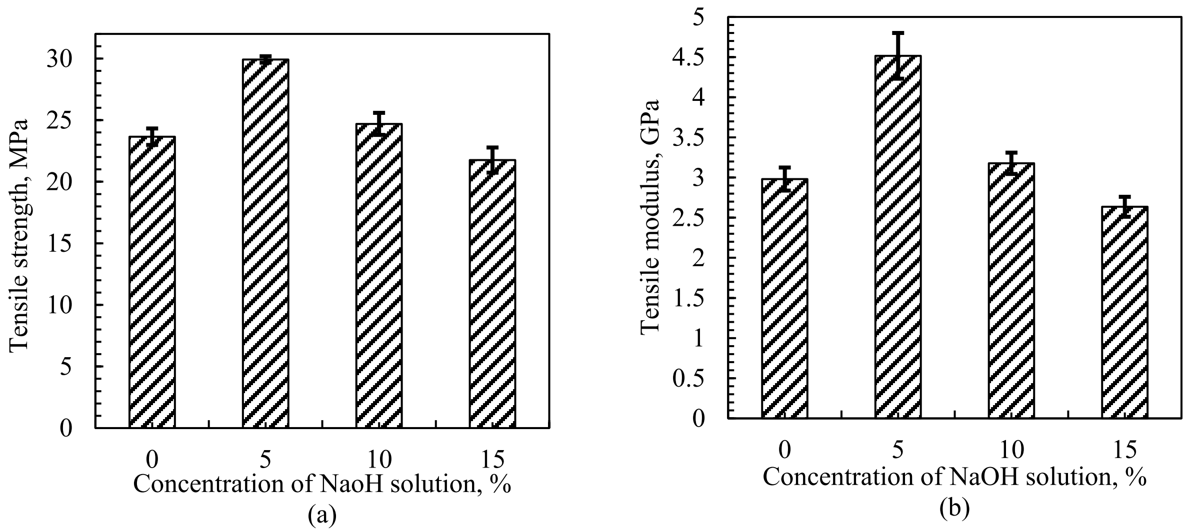


Figure 2. (a) Tensile strength (b) Tensile modulus of the fabricated composites.

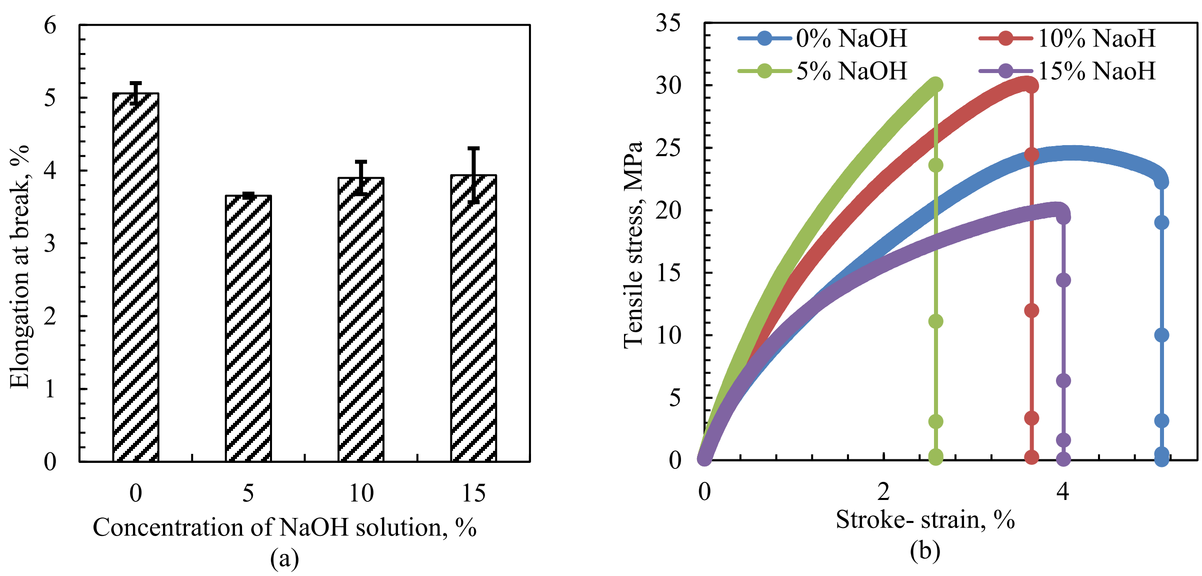


Figure 3. (a) Elongation at break (b) Stress-strain curves of the fabricated composites.

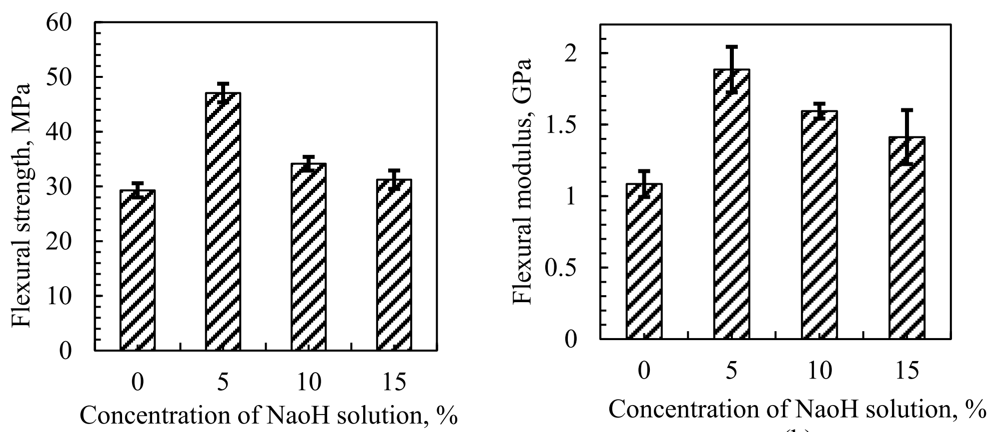
The significant increase in tensile properties at 5% NaOH treatment implies that the surface modification of the treatment significantly increased the effective load distribution and stress transmission mechanism inside the composite structure by improving the fiber-matrix contact. The following reduction in tensile strength and tensile modulus for the 10% and 15% NaOH treatments, however, may be due to possible changes in the fiber's surface morphology, deterioration, or other structural alterations brought on by the higher NaOH concentrations. These factors might cancel out the early benefits of surface treatment, resulting in a decrease in tensile strength and tensile modulus.

The elongation at break during tension test for treated and untreated composites is shown in Fig.3 (a). Elongation at break for the untreated composite was 5.06%. Composites treated with 5% NaOH showed a 27.75% decrease in elongation at break compared to the untreated one. Similarly, the 10% and 15% NaOH treatment showed a linear increase in elongation at break but remained less than the control composite. The considerable drop after the 5% NaOH treatment indicates that the material's ductility was affected in a way that decreased its capacity for plastic deformation before fracture due to a better fiber-matrix interaction. However, an increasing trend in the elongation at break and a decreasing trend in the tensile strength and modulus indicate that the contribution of fiber reinforcement is decreased. This may have happened because of the damaged fibers after treatment using a higher concentration of NaOH. When fibers are damaged the contribution of the polymer on the properties of the composite becomes prominent resulting in a lower strength, modulus, and higher elongation at break.

The stress-strain graph for the fabricated composites is shown in Fig.3 (b). This graph shows how different NaOH treatments influence the materials' behavior during the deformation for both treated and untreated composites. The fiber treatment using 5% NaOH shows a higher load-bearing capacity and lower breaking strain. The treatment of fibers using more higher concentration of NaOH caused a decrease in load-bearing capacity but the elongation at break is increased.

4.2 Flexural Properties

The flexural strength and modulus of the fabricated composites are shown in Fig. 4. The flexural strength and modulus of the untreated composite were found to be 29.28 MPa and 1.08 GPa, respectively. The flexural strength and modulus of the composite treated with 5% NaOH were increased to 47.05 MPa and 1.88 GPa, respectively. These correspond to a remarkable 60.77% and 74.07% gain in flexural strength and modulus, respectively over the composite that wasn't treated. Following a 10% NaOH treatment, both the flexural strength and modulus dropped gradually similar to the observation for tensile properties as discussed earlier. The decreasing trend in the flexural strength and modulus is attributed to the fiber damage due to treatment using a high concentration of NaOH.



(a) (b)

Figure 4. (a) Flexural strength and (b) Flexural modulus of the fabricated composites.

When these results are analyzed, the notable improvement after the 5% NaOH treatment highlights the significant impact of surface modification on enhancing the composite's capacity to resist bending forces and its stiffness. This extraordinary improvement can be attributed to the treatment's more effective interfacial characteristics, which in turn led to increased adhesion between the fibers and the matrix. The significant improvement in both flexural strength and modulus at this particular treatment level emphasizes the critical importance of enhanced fiber-matrix interaction, which in turn enables superior stress distribution and load-bearing capacities.

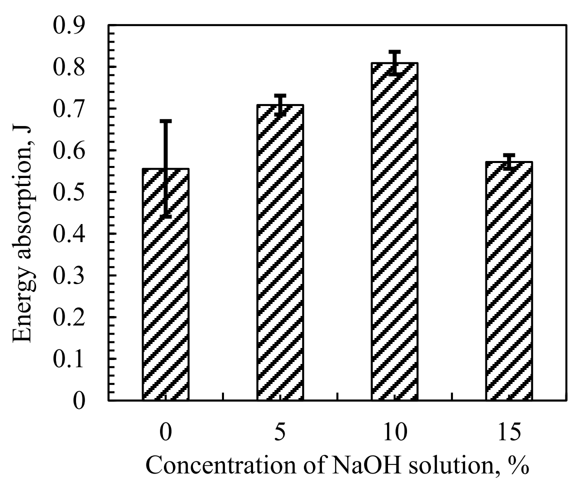


Figure 5. Energy absorption of the fabricated composites.

The energy absorption during the bending test of the fabricated composites up to 11 mm displacement during the flexural test is shown in Fig. 5. The energy absorption of the untreated composite was found to be 0.55 J. A linear increase in energy absorption was seen after the jute fibers were treated with 5% and 10% NaOH, yielding values of 0.70 J and 0.80 J respectively. Comparing this to the untreated composite, the percentage increases were 27.27% and 45.45% respectively. The energy absorption of the composites fabricated after treating the fibers using 15% NaOH is decreased to 0.57 J. The significant improvements at the 5% and 10% NaOH treatments imply that the material's capacity to absorb energy during deformation was significantly increased by these treatment concentrations, possibly as a result of improved fiber-matrix interaction and altered composite characteristics. However, the reduction in energy absorption with 15% NaOH treatment may be due to the considerable damage to the fibers by the stronger treatment solution, which might have affected the material's capacity to absorb energy.

5.0 Conclusion and Future Research

The effects of NaOH treatment on the mechanical characteristics of randomly distributed non-woven jute/epoxy composites were investigated in this study. A complex link between treatment concentration and some mechanical characteristics was found in this investigation. The composites fabricated using fibers treated with 5% NaOH concentration, in particular, demonstrated a notable improvement in tensile strength, flexural strength, tensile modulus, flexural modulus, and energy absorption. The improvements were attributed to the increased fiber-matrix adhesion brought on by the treatment. The study also identified the threshold for NaOH concentration to be 5% NaOH. Increasing the concentration degrades the mechanical performance of the composites. The treatment of fiber may be a blessing for improving the properties of the fiber-reinforced composite materials but the concentration of alkali solution plays an important role in the mechanical properties of the composites because of the possibility of fiber damage at higher concentration.

To further improve the mechanical properties of jute fiber composites, future studies should concentrate on improving treatment parameters, taking into account elements like NaOH content, treatment duration, and alternative surface modification approaches. Future research may concentrate on assessing the environmental sustainability of these composites and investigating eco-friendly treatment options to meet the increasing demand for green engineering techniques. Expanding the usability and economic relevance of NaOH-treated jute composites in various industries can be achieved by investigating their multifunctional capabilities and specialized applications, such as self-healing characteristics or use in automotive and aerospace components.

References

Ashraf, M. A., Zwawi, M., Taqi Mehran, M., Kanthasamy, R., & Bahadar, A. Jute based bio and hybrid composites and their applications. *Fibers*, *7*(9), 77, 2019.

Behera, S., Kumar Gautam, R., Mohan, S., & Chattopadhyay, A. Mechanical and tribological properties of chemically modified jute/epoxy composites. *Plastics, Rubber and Composites*, 1-13, 2023.

Boopalan, M., Umapathy, M., & Jenyfer, P. A comparative study on the mechanical properties of jute and sisal fiber reinforced polymer composites. *Silicon*, *4*, 145-149, 2012.

Cottrell, J. A., Ali, M., Tatari, A., & Martinson, D. B. Effects of Fibre Moisture Content on the Mechanical Properties of Jute Reinforced Compressed Earth Composites. *Construction and Building Materials*, *373*, 130848, 2023.

Gopinath, A., Kumar, M. S., & Elayaperumal, A. Experimental investigations on mechanical properties of jute fiber reinforced composites with polyester and epoxy resin matrices. *Procedia engineering*, *97*, 2052-2063, 2014.

Gunge, A., Koppad, P. G., Nagamadhu, M., Kivade, S., & Murthy, K. S. Study on mechanical properties of alkali treated plain woven banana fabric reinforced biodegradable composites. *Composites Communications*, *13*, 47-51, 2019.

Haque, M. M., & Hasan, M. Influence of fiber surface treatment on physico-mechanical properties of betel nut and glass fiber reinforced hybrid polyethylene composites. *Advances in Materials and Processing Technologies*, *4*(3), 511-525, 2018.

Islam, S. R., Alassod, A., Patoary, M. K., Naveed, T., Ali, M. A., & Jiang, J. Study on Thermal, Thermo-Mechanical, and Flexural Properties of Jute Fiber Surface Modification and Its Reinforced Composite. *AATCC Journal of Research*, *8*(5), 11-17, 2021.

Jahan, E., Akter, M., & Hasan, M. Effect of fiber ratio and chemical treatment on the properties of pineapple leaf and betel nut husk fibre-reinforced hybrid polypropylene composites. *Advances in Materials and Processing Technologies*, *6*(3), 637-646, 2020.

Judawisastra, H., Sitohang, R., & Rosadi, M. Water absorption and tensile strength degradation of Petung bamboo (Dendrocalamus asper) fiber—reinforced polymeric composites. *Materials Research Express*, *4*(9), 094003, 2017.

Kapatel, P. M. Investigation of green composite: Preparation and characterization of alkali-treated jute fabric-reinforced polymer matrix composites. *Journal of Natural Fibers*, *18*(4), 510-519, 2021.

Karabulut, N., Aktaş, M., & Balcıoğlu, H. E. Surface modification effects on the mechanical properties of woven jute fabric reinforced laminated composites. *Journal of Natural Fibers,* 2018.

Kurien, R. A., Anil, M. M., Mohan, S. S., & Thomas, J. A. Natural fiber composites as sustainable resources for emerging applications-a review. *Materials Today: Proceedings,* 2023.

Mahesh, V., Mahesh, V., & Harursampath, D. Influence of alkali treatment on physio-mechanical properties of jute–epoxy composite. *Advances in Materials and Processing Technologies*, *8*(sup2), 380-391, 2022.

Nagarajan, S., Skillen, N. C., Irvine, J. T., Lawton, L. A., & Robertson, P. Cellulose II as bioethanol feedstock and its advantages over native cellulose. *Renewable and Sustainable Energy Reviews*, *77*, 182-192, 2017.

Negawo, T. A., Polat, Y., Buyuknalcaci, F. N., Kilic, A., Saba, N., & Jawaid, M. Mechanical, morphological, structural and dynamic mechanical properties of alkali treated Ensete stem fibers reinforced unsaturated polyester composites. *Composite Structures*, *207*, 589-597, 2019.

Nurazzi, N. M., Khalina, A., Sapuan, S. M., & Rahmah, M. Development of sugar palm yarn/glass fiber reinforced unsaturated polyester hybrid composites. *Materials Research Express*, *5*(4), 045308, 2018.

Rajeshkumar, G., Hariharan, V., Indran, S., Sanjay, M., Siengchin, S., Maran, J. P., Al-Dhabi, N. A., & Karuppiah, P. Influence of sodium hydroxide (NaOH) treatment on mechanical properties and morphological behavior of Phoenix sp. fiber/epoxy composites. *Journal of Polymers and the Environment*, *29*, 765-774, 2021.

Roy, A., Chakraborty, S., Kundu, S. P., Basak, R. K., Majumder, S. B., & Adhikari, B. Improvement in mechanical properties of jute fibers through mild alkali treatment as demonstrated by utilisation of the Weibull distribution model. *Bioresource Technology*, *107*, 222-228, 2012.

Saha, P., Manna, S., Chowdhury, S. R., Sen, R., Roy, D., & Adhikari, B. Enhancement of tensile strength of lignocellulosic jute fibers by alkali-steam treatment. *Bioresource Technology*, *101*(9), 3182-3187, 2010.

Sarker, F., Uddin, M. Z., Sowrov, K., Islam, M. S., & Miah, A. Improvement of mechanical and interfacial properties of hot water and sodium bicarbonate treated jute fibers for manufacturing high performance natural composites. *Polymer Composites*, *43*(3), 1330-1342, 2022.

Singh, J. I. P., Singh, S., & Dhawan, V. Effect of alkali treatment on mechanical properties of jute fiber-reinforced partially biodegradable green composites using epoxy resin matrix. *Polymers and Polymer Composites*, *28*(6), 388-397, 2020.

Sinha, E., & Panigrahi, S. Effect of plasma treatment on structure, wettability of jute fiber and flexural strength of its composite. *Journal of composite materials*, *43*(17), 1791-1802, 2009.

Wang, X., Chang, L., Shi, X., & Wang, L. Effect of hot-alkali treatment on the structure composition of jute fabrics and mechanical properties of laminated composites. *Materials*, *12*(9), 1386, 2019.

Biographies

Raju Ahammad is a lecturer in the Department of Mechanical Engineering at Khulna University of Engineering & Technology. He completed his BSc in ME from the same department. Currently, he is a master's student of the same department. He is working on microparticle-filled composites, fiber-reinforced polymer matrix composites, and fiber metal laminates. His field of interest is in the mechanics of composite materials, nano and micro composites. He has published several research papers in the above fields.

Md. Arifuzzaman is an experienced academic holding a Doctor of Philosophy (Ph.D.), focused on Construction Materials from The University of Newcastle, Australia. He completed his BSc and MSc in ME from the Department of Mechanical Engineering of Khulna University of Engineering & Technology. He is working as a professor of Mechanical Engineering at Khulna University of Engineering & Technology (former BIT, Khulna), Bangladesh. He taught several courses at the undergraduate and postgraduate levels and supervised many students at the undergraduate and postgraduate levels. He has been awarded several prestigious awards and scholarships throughout his academic career. His field of interest is in composite materials, building materials, sandwich structures, lightweight particles-filled building materials, fiber-reinforced composites, and FEA of materials. He has published many peer-reviewed journals and conferences/proceedings in the above area.

Dr. Md. Shariful Islam is currently working as a professor in the Department of Mechanical Engineering at Khulna University of Engineering & Technology. Dr. Islam has earned his Ph.D. and M.Sc. in Mechanical Engineering from The University of Texas at El Paso, USA, and his B.Sc. in Mechanical Engineering from Khulna University of Engineering & Technology, Bangladesh. Dr. Islam's research interest includes Textile Composites, Natural Fiber Composites, and Multi-scale Material Modeling. He has published many research papers in the above area.