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# Mechanical and Morphological Comparison of Naoh-Treated Banana Fiber Reinforced Glass Fiber

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**Abstract:** In addition to having excellent mechanical qualities, banana fibre is a naturally occurring fibre material that is available in vast quantities. By producing hybrid composite materials that are in great demand, we are able to make use of those features in the field of mechanical engineering. The purpose of this study is to analyse the hybrid composite material t hat is created from banana fibre and S2 glass fibre and reinforced with epoxy resin and hardener HY951. The creation of the first sample was accomplished by the use of the hand lay-up technique, whereas the second sample was made by treating the banana fibre with a solution of sodium hydroxide. The preparation of the sample involves the distribution of a uniform compression load. Finally, the produced samples were tested for tensile and flexural strength in accordance with ASTM standards in order to evaluate the differences and similarities between the two samples. The findings indicate that the sample that was not treated with NaOH possesses a high tensile strength, whereas the solution that was treated with NaOH demonstrates a high flexural test. The scanning electron microscope (SEM) is used to analyse the morphological characteristics, which results in a strong bonding strength for the engineering application.

**Keywords:** Banana Fiber; Glass Fiber; Epoxy Resin; Hand Lay-up Method; Tensile Test; Flexural Test; Morphological Study; S2 Glass Fibre; Flexural Testing Machine.

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**Introduction**

At the microscopic level, a material that is assembled from two or more different components is utilised. Heterogeneous on a microscopic size, yet homogeneous on a macroscopic scale in terms of its statistical properties. There is a major difference in the characteristics of the constituent components [5]. It is expected that the mix of materials would result in significant changes to the properties. The percentage of the element that is present is typically greater than ten percent [6]. One of the constituents has a property that is much higher (at least five times higher) than the other. Where can we find the oldest application of composite material that has ever been used? Laminated writing material derived from the papyrus plant dates back to 4000 B.C [7-12]. Straw bricks were utilised by the Egyptians and Mesopotamians around 1300 B.C. and 1200 A.D. The Mongols were the first people to create a composite bow. The percentage of fibre-reinforced polymers (FRP) that are used in the material cycle has been steadily growing over the past few years in the aviation, automotive, construction, and sports industries, respectively [13-17]. On the other hand, this does not typically apply to FRP because the material contains a significant number of organic components [18].

Additionally, the legal recycling rates, such as 95 percent in the automotive industry and 70 percent for construction and demolition waste (Waste Framework Directive 2008/98/EG, (European Parliament and Council, 2008)), raise urgent questions regarding the recovery of materials, the reuse of materials, and the impact that fibres and GFRP waste have on the environment [19-22]. For the purpose of enhancing the qualities of each component, the natural fibres lead to the production of composites that contain an amalgamation of matrix information. The various matrices that are now being utilised distinguish themselves from natural fibres by being flexible and soft [23-27]. The combination of these matrices results in the development of composites that have high strength-to-weight ratios. The features of hybrid reinforced composites made of flax include their mechanical, thermal, and thermo-mechanical qualities [28-31]. Additionally, it has been discovered that increasing the number of preformed layers results in laminate composites that yield high stress with low strain to failure. Additionally, increasing the volume fraction of fibre results in improved tensile strength while simultaneously reducing compressive strength during the yielding process [32-35].

In order to provide greater mechanical qualities, the combined laminates perform the function of a layer of skin. The results of the chemical treatment and layering sequence were assessed by R. Yahaya and colleagues on composites made of Kevlar and Kenaf components [36-39]. The properties of hybridization, such as flexural and tensile composites, show enhanced results when compared to composites that do not contain hybridization. It has been demonstrated through the findings that the Hybrid natural fibre composite (HNFC) exhibited improved performance when loaded with thirty-weight percent of fibre. Tensile strength of HNFC at 30 weight percent is 68 MPa, the flexural strength of HNFC at 30 weight percent is 72 MPa, and the hardness of HNFC at 30 weight percent fibre loading is 89 RHN. All of these values are measured at 30 weight percent. When compared to the pure Jute and pure banana fibre composite, these results regarding HNFC at a weight percentage of thirty percent are superior. Therefore, the mechanical qualities will be improved by combining fibres with epoxy in a specific weight ratio and arranging them in a variety of orientations [40-44]. Constructed from at least two or more constituent materials that have considerably diverse chemical or physical properties, composite materials are designed materials that are formed from these constituent materials. Within the final building, these materials continue to exist in a separate and unique manner at the macroscopic level. The unique features of the composite are a result of the working relationship between the various constituents. It should be noted that the attributes of these new components are distinct from those of the individual elements. However, within the composite, it is very easy to recognise that the various elements are distinct from one another;

they do not have the ability to dissolve or blend into one another [45-49].

For a variety of reasons, including the fact that it is more durable, lighter, or less expensive than other materials, the new material might be favoured. Containers were crafted by ancient Egyptians using coarse fibres that were drawn from heat, typically glass dd btdiltlt1200ºC. This was accomplished by extruding molten glass at 1200ºC, passing it through a spinner set of 1-2mm diameter, and then drawing the filaments to produce fibres with a diameter ranging from 1-5μm [50-55]. The width of each individual filament is rather small; it behaves in an isotropic manner, and it can take on a wide variety of forms. Glass fibres, in general, have an isotropic structure. There are several applications for composites made of glass fibre and Kevlar fibre that are used in the aerospace industry. Not only that but aviator tails and helicopter blades have also been designed [56-61]. The use of those composite materials is also chosen for stabilising emergency exits (Figure 1).

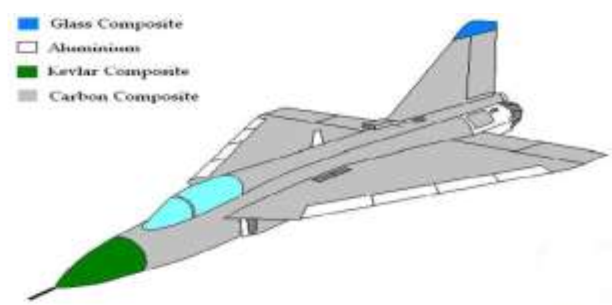


Figure 1: Contribution of composite in aero field

When it comes to the weight of the military, there is a need for less equipment that can be lifted by humans, and defence technology is attempting to meet this demand. Because of its high strength and low weight, composite material is their material of choice [62-68]. When it comes to construction, composite materials that consist of concrete bricks and other components are extremely important. Characteristics that are exhibited by composite materials include high compressive resistance, high heat resistance, and shock absorbent properties [69-73]. There is no advancement in the field of automobiles that does not involve the development of material alternation, which refers to the incorporation of composite materials into the automobile. Composite materials are used in the construction of the door, cabin, dashboard, and other components. Submissive material should have a high level of corrosion resistance. As a result of the fact that composite materials are known to possess corrosion resistance, they are extensively utilised in maritime applications [74-79]. All propeller shaft bearings that are lubricated with water are constructed utilising composite material.

**Literature Survey**

The tensile, flexural, and hardness behaviour of the hybrid natural fibre composite (HNFC) was described by Shireesha et al. [1] as being prepared and characterised by the hybrid natural fibre composite. According to the findings, the HNFC composite exhibited greater performance than both pure Jute and pure banana fibre composite. At 30 weight percent, the tensile strength of HNFC is 68 MPa, the flexural strength of HNFC is 72 MPa, and the hardness of HNFC with 30 weight percent fibre loading is 89 RHN. All of these values are measured against the fibre loading. When compared to the pure Jute and pure banana fibre composite, the outcomes of HNFC at a weight percentage of thirty percent are superior. Therefore, the mechanical qualities will be improved through the amalgamation of fibres with epoxy at a specific weight ratio and in a variety of orientations.

According to Khasim Sharif and his colleagues [2], the fibre that is used in the fabrication of composite materials is jute laminate. This information was provided based on their findings. Epoxy glue is utilised in the hand lay-up process to make jute and banana fibre. This procedure is made possible by the usage of epoxy glue. An examination of the composite material's tensile strength was carried out, and the results revealed that the material had an average value of 6.98 MPa. Increasing the amount of alterations that are made to the amalgamation will lead to an improvement in the mechanical properties of the materials. It is anticipated that the composite will see an improvement in its properties as a consequence of the application of NaoH.

The group of researchers known as Sevkat et al. [3] conducted a survey and review on the characteristics of S2-type glass fibre. Epoxy resin was employed, and there were 24 layers of S2 glass fibre in the resin. All of the samples were subjected to a drop test. It has been discovered that it is able to resist a greater number of impacts. Both the impact test and the dynamic strain, as well as the numerical research of S2, have produced satisfactory results. According to the results of all of the mechanical and numerical tests, it is clear that the composite material made of glass fibre has a high impact impact strength.

The hand lay-up approach was utilised in the preparation of Marimuthu et al. [4]. In order to carry out a variety of mechanical tests, they chose to combine glass fibre with coconut fibre. As a consequence, glass fibre constitutes the majority of the whole. The results of this study demonstrate that a straightforward hand lay-up process may be used to successfully fabricate hybrid fibre-reinforced epoxy composites. These composites are subjected to testing to determine their mechanical properties in accordance with the standards established by the ASTM.

Material Requirement

Glass wool, which is now commonly referred to as "fibreglass," was initially developed by Russell Games Slayter of Owens-Corning in 1932–1933 as a construction material for the purpose of providing thermal insulation for buildings. The trade name Fiberglas, which has evolved into a generic trademark, is used by the manufacturer to sell the product. When used as a thermally insulating material, glass fibre is made in a unique way with a bonding agent to trap a large number of microscopic air cells. This results in the family of goods known as "glass wool," which is characterised by its low density and distinctive air-filled properties [80-85]. Polymers and carbon fibre are two examples of other types of fibres that have mechanical properties that are roughly comparable to those of glass fibre. When used in composites, it is substantially less brittle and significantly cheaper than carbon fibre, despite the fact that it is not as rigid as carbon fibre. Therefore, glass fibres are utilised as a reinforcing agent for a wide variety of polymer products in order to create a composite material that is both extremely robust and relatively lightweight [86-91]. This material is known as glass-reinforced plastic (GRP), which is also commonly referred to as "fibreglass."

Extruding thin strands of silica-based or other formulation glass into multiple fibres with small diameters that are suitable for textile processing results in the formation of glass fibre. Despite the fact that the process of heating and drawing glass into fine fibres has been known for millennia, the utilisation of these fibres for applications in the textile industry is a relatively new development [92-96]. All of the glass fibre that had been produced up until this point had been used as staples (clusters of short lengths of fibre). Magnesium aluminosilicates are used in the production of high-strength glass, known as S-glass [97-101]. Utilized in situations where there is a requirement for high strength, high stiffness, resilience to extreme temperatures, and resistance to corrosion, S-2 glass is comparable to S-glass but has qualities that are somewhat superior to those of S-glass. Originally developed by Owens-Corning, the brand name "S-2" was eventually separated from the company in 1998 and is now a registered trademark of AGY Holdings Corporation [102-107].

Banana fibre is a type of lignocellulosic fibre that is derived from the pseudo-stem of the banana plant (Musa selenium). It is a bast fibre that possesses reasonably strong mechanical qualities. In addition to their usage in the textile, paper, and handicraft sectors, banana fibres can also be used in a variety of other applications. It is possible to remove fibres from the pseudo-stem leaves of the banana using a decorticator machine [108-111]. This machine is capable of removing bark, skin, wood, stalk, and grain from the plant. As soon as the leaves of the pseudo-stem are chopped, the extraction process is carried out [112-127]. A mix of water retting and scraping is the procedure that is most commonly used in industrial settings.

**Epoxy Resin and Hardener**

Epoxy resins are a significant and diverse type of cross-linkable polymers that are formed from monomers that include at least two oxiranes, which are strained-ring groups. The electrical qualities, chemical resistance, strength, and low moisture absorption of epoxy resins are some of the characteristics that distinguish them from other epoxy resins. Their resistance to corrosion (solvents, alkalis, and some acids) is particularly excellent, and they also have a high strength-to-weight ratio, dimensional stability, and adhesive qualities [128-131]. They are versatile resins. Depending on the formulation, they can be either liquid or solid, and they can be cured either at room temperature or with heat. The use of heat curing is increasingly prevalent in circumstances where the highest possible performance is required. In general, the curing time for epoxy resins is longer than that of other thermoset resins. Although cold-cure varieties are available, the performance of the product is typically improved when it is cured at temperatures between 40 and 60 degrees Celsius [132-136]. An extensive range of industries, including aerospace and defence, chemical plants, and high-performance automotive applications, make frequent use of epoxy materials. Within the scope of this project, we have utilised one hundred percent resin and ten percent hardener.

The treatment with alkali is one of the most effective procedures for the solubilization of complex organic matter products. Solvation and saponification are the primary reactions that take place during alkali treatment. These reactions lead to the swelling of the particulate organics, which in turn makes the cellular substances more susceptible to enzymatic attack. As a result, the biodegradability of both the solid and liquid phases is improved. The solubilization of carbon dioxide (COD) is increased through the saponification of uranic acids, acetyl esters, and lipids. This process results in the solubilization of membranes and the release of intercellular material, as well as the neutralisation of various acids that are formed as a result of the degradation of particulate organics. When the pH of the environment rises, the negatively charged surfaces of bacteria become more negatively charged, which leads to an increase in electrostatic repulsion. This, in turn, causes some of the extracellular polymer to desorb. In the sequence of sodium hydroxide (NaOH), potassium hydroxide (KOH), magnesium hydroxide (Mg(OH)2), and calcium hydroxide (Ca(OH)2), the alkali that was added to the sludge had the highest efficiency. Na+ or K+ concentrations that are very high, on the other hand, may hinder Alzheimer’s disease growth. However, it is important to note that throughout the alkali treatment process, some of the alkali is absorbed by the biomass itself, which results in an increase in the amount of alkali reagents that are consumed during the process.

Table 1: Components Table

| No | Material | Specification Or Grade | Quantity |
|---|---|---|---|
| 1 | Glass Fiber | S 2 type | One sq meter |
| 2 | Banana Fiber | Acetone treated | 1 Kg |
| 3 | Epoxy resin | LY556 | 500ml |
| 4 | Hardner | HY951 | 1500ml |
| 5 | NaOH | - | 250ml |
| 6 | Roller | Cotton roll | 1 |
| 7 | Beaker | 250ml | 1 |

**Fabrication Process**

More than fifty processes, depending on the nature and kind of the matrix and the fibres it contains The following processes are utilised: hand lay-up spray lay-up vacuum bagging filament winding pultrusion resin transfer moulding (RTM) braiding vacuum assisted RTM centrifugal casting. Hand lay-up is a technique that we have chosen to apply in this situation since it is relatively straightforward, and we have chosen to use fibre material composites.

**Steps Involved In the Preparation of Naoh Treated Sample**

**STEP 1:** The sample is prepared using S2 glass and banana fibre. First, the S2 glass fibre is placed on the base material and rolled using the roller to remove any foldings present.

**STEP 2:-** Apply the resin after mixing it with hardener in the correct proportion.

**STEP 3:** After the resin is applied to the S2 glass fibre, the banana is placed on the S2 glass horizontally, and the resin is applied to it again.

**STEP 4:-** After some time, one more S2 glass fibre is applied.

**STEP 5:-** The second layer of banana fibre is applied vertically over the S2 glass. Again, the resin mixture is spread over it.

**STEP 6:-** The final topmost layer of glass fibre is spread and rolled with the help of a roller.

**STEP 7:-** The prepared frame is fixed on the sample, the load is applied for 24-28 hours, and the sample is removed from the base.

**Result And Discussion**

Tensile testing, which is often referred to as tension testing, is a fundamental test in the field of materials science and engineering. In this test, a sample is exposed to controlled tension until it fails. The ultimate tensile strength, breaking strength, maximum elongation, and reduction in area are the properties that can be directly assessed through the administration of a tensile test. A total of six specimens, both treated with NaOH and untreated, were selected. In order to verify that the specimens do not have any notching or cracks that are the result of manufacturing or surface defects, which could have a negative impact on the tensile testing, it is necessary to take this precaution. On the computer system that was connected to the Insight MTM machine, the relevant information on the gauge length and width of the specimen was inputted before the specimens were loaded into the machine. This was done before the machine was loaded with specimens [137]. Following that, the computer system was assembled so that it could record data and produce the required load-deflection graphs. An examination of the specimens' tensile strength was carried out after they were placed into the Insight MTM machine. The data was stored digitally in text files, as can be seen in Appendix B, and the load-deflection curve was displayed on the screen of the computer as a visual representation of the data (Figures 2 and 3).

**Figure 2:** specimen before

**Figure 3:** Specimen after testing

Both the flexural modulus and the flexural strength of a material may typically be determined through the use of flexure tests. The results of a flexure test are slightly different from those of a tensile test, but the flexure test is more cost-effective. Over two points of contact, the material is laid out in a horizontal orientation (lower support span). A force is then applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. This process continues until the sample fails.

Therefore, the flexural strength of that particular sample is equal to the greatest force that was recorded. A total of six specimens, both treated with NaOH and untreated, were selected. As required by the ASTM requirements, specimens were collected. A flexural testing machine was utilised throughout the process to determine the maximum flexural strength of the specimens. By entering the essential information regarding the gauge length and width of the specimen, the computer system that was connected to the Insight MTM machine was prepared to load the specimens into the machine. This was done before the specimens were loaded into the machine. Following that, the computer system was assembled such that it could record data and produce the load-deflection graphs that were required. An examination of the specimens' flexural strength was carried out after they were placed into the Insight MTM machine. Text files were used to electronically record the data, and a visual depiction of the load-deflection curve was displayed on the screen of the computer (Figure 4).

**Figure 4:** Flexural testing machine

A scanning electron microscope, often known as a SEM, is a type of electron microscope that generates images of a material by scanning the surface with a focussed stream of electrons during the imaging process. Because of the interaction between the electrons and the atoms in the sample, a variety of signals are produced. These signals carry information on the surface topography and composition of the sample. The electron beam is scanned in a raster scan pattern, and the position of the beam is combined with the strength of the signal that is detected in order to form a picture. According to the results of the tensile test that was performed on composite samples that had been treated with NaOH and those that had not been treated with NaOH using the universal testing machine, the non-NaOH treated composite had a maximum tensile strength that was 28 percent higher than the NaOH NaOH-treated composite.

Taking the flexural test using the flexural testing machine for NaOH-treated and Non-NaOH treated composite samples results in the Non-NaOH treated composite having maximum flexural properties compared to the treated composite (Table 2).

**Table 2. Flexural test of a non-NaOH sample**

| Flexural Test | | | |
|---|---|---|---|
| **Tested Parameters** | **Peak load(KN)** | **Ultimate tensile Stress(Mpa)** | **Modulus(Mpa)** |
| Sample 1 | 105 | 32 | 13105 |
| Sample 2 | 101 | 29 | 12945 |
| Sample 3 | 106 | 35 | 13305 |

**Conclusion**

In this process, banana fibres are combined with sodium hydroxide (NaOH), and non-amalgamated banana fibre is reinforced with an epoxy matrix that contains S2 glass fibre. In this study, a hybrid natural fibre composite (HNFC) is created and characterised for its tensile, flexural, and morphological behaviour. According to the findings, the hybrid natural fibre composite (HNFC) that was not treated with sodium hydroxide (NaOH) demonstrated superior performance when subjected to the tensile test. It achieved a maximum tensile strength of 28 percent, which was higher than the composite that was treated with sodium hydroxide. In the flexural test conducted with the flexural testing machine on composite samples that were treated with NaOH and those that were not treated with NaOH, the results showed that the non-NaOH treated composite had the highest flexural properties in comparison to the treated composite. Therefore, the flexural property of the material is improved when fibres are combined with sodium hydroxide at a specific weight ratio inside the material.

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