Static investigation of roselle waste powder reinforced bio polymer composite

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Abstract: Today the entire research community is looking for sustainable materials. In that process, more research is going on to utilize the natural materials as binders, fillers, reinforcement etc., to enhance the mechanical and thermal properties without affecting the nature. Numerous amount of research is carried out various regions of the world on the usage of pine, sisal, hemp, bagasse, jute, bamboo, coir as reinforcement. This study focuses on the utilization of agro waste like Roselle (Hibiscus Sabdariffa) as reinforcement material in epoxy LY 556 matrix along with different volume percentage of natural filler to form a unique bio based composite material. The composite specimens were fabricated by vacuum bag moulding method. The mechanical properties of the fabricated specimen at different compositions is studied. The maximum mechanical properties were observed for the composite with 30:70 volume percentage Hibiscus sabdariffa with epoxy resin added composition. From the results we can conclude the composite developed using Roselle powder and LY 556 epoxy would be very good alternate for various light weight material applications.

Keywords: Biogas, Cow dung, vegetable waste, pH, anaerobic.

1. Introduction

The usage of polymers and synthetic fibers as reinforcements in various areas like automotive applications, sports products, construction materials and bio medical applications has seen a sharp rise in the recent times. At the same time, the concern about the environment and its depletion makes the people to think about the ecofriendly material [1-3]. The utilization of the sustainable materials will pave way for making the environment cleaner and greener. Other issue is that, the handling of synthetic fibers and its post processing. Synthetic fibers possess great big threat to environment and human health. Hence, the exploration of alternative materials in place of synthetic fibers leads to numerous investigation and examination of various natural materials as sustainable alternate reinforcement of polymers [4-7]. There are three different classifications of natural fibers by means animal fiber, mineral fiber and plant fiber. The major constituents of plant fibers are cellulose, hemi cellulose, lignin and ash. Each constituent has a specific role to play. The cellulose contents decide the physical and mechanical
behavior of the composite material. The biodegradable nature of the material is depending upon the hemicellulose content in the material. The lignin acts as binder but possess poor mechanical property.

The roselle is lignocellulosic in nature. It has twisted helix like cellulosic structure bounded by hemicellulose matrix and lignin. The bio fibers have numerous advantages like easy availability, economical, biodegradable, it can be recycled, possess better energy recovery, can be easily processed, nontoxic in nature on comparing with synthetic fiber and eco-friendly. In addition to all these, natural materials hold very good mechanical characteristics. These are all the reasons behind choosing the natural fibers as reinforcements for polymers [7-10]. Roselle, botanically known as Hibiscus Sabdariffa belongs to the family of Malvaceae, a bast fibre [11]. It is believed that this plant has Asia or tropical Africa as its native. In India, the plant is called in various names in various regions. For example, Gongura in Hindi, Pulichchai Keerai in Tamil, Yerra Gogu in Telugu, Polechi in Malayalam, Pundibija in kannada. It shows the abundancy in availability of this plant in India. The plant is about 3.5 m tall and has a deep taproot system. It is an annual plant. These plants are edible, cultivated mainly for calyces, fruits and stem fiber [12-15]. After 15 – 20 days of flowering the calyces are collected and rest of the plant in left in the field for threshing. Long steam without branches from the agro waste is utilized to produce fiber. The rosella is lignocellulosic in nature. So it has poor wettability and moisture absorbing capacity. Thus resisting the hydroxyl groups from reacting with polar matrices. Hence it cannot from an interlock while using it as reinforcement [17]. In order to reduce the above said disadvantage, the fiber is chemically or physically treated [18]. These treatment methods make it compatible with polymer medium. There are various treatment methods are available like copolymerisation, acetylation, permanganate treatment etc. Currently there is limited amount of studies are available on the utilization of Roselle as filler [19]. This is the main reason behind carrying out this work.

In this research work, rosella powder was taken as the filler material as reinforcement agent. Along with that, epoxy resin has been chosen as the matrix material, both the materials have been combined together in order to have the eco based composite material. Besides that, to evaluate the mechanical behaviour of the system, tests like flexural, tensile and impact have been performed and the results are compared with each other.

2. Materials and method

2.1 Chemical composition of roselle powder

The Chemical properties of Roselle were contrasted with the composition of selected samples. The fiber contains 20.46 % of hemicellulose, 65.49 % of cellulose, 5.41 % lignin and 0.53 % of ash. The comparison of chemical composition between various important natural fibers.

2.2 Fibre

The fiber from the collected Roselle (Hibiscus sabdariffa) plants were extracted by water retting process for seven days. The plants are thoroughly washed in running water and the fibers are removed from the plant by hand. Followed by drying them in sun light and powdered.

2.3 LY556 Epoxy resin

Combination of two or more than two group of epoxy constitutes an epoxy resin. Thermoset and thermoplastic polymers are differentiated by using epoxy resin. The molecular structure of epoxy resin possess very limited shrinking capacity and reluctant to stress. Thus it exhibits good mechanical properties. Epoxy resin bonds with wide range of substances due to its organic nature. In addition, the limited shrinkage in molecular structure helps in strong adhesion. It possess very high resistance to acids, solvent and alkalinity. Epoxy are very good insulators with good dielectric property. It possess
desirable properties like fungal resistance, structural stability, thermal resistance, least aqua absorption and it’s a poor moistness transmitter.

2.4 Test specimen preparation

Suitable quantity of Roselle fiber powder and LY 556 Epoxy were taken and mixed continuously to get a uniform mixture. The hardener was added and mixed briskly for about 10 to 15 min. the mixture is transformed into the vacuum bag mold and compressed evenly. The mold is left for about 24 to 36 hrs for curing, then the board is taken out of the mold. Seven composite specimens were fabricated with different volume fraction percentage of Hibiscus sabdariffa and epoxy matrix as shown in Table 1. The samples for various mechanical testing like flexural, tensile, impact, and moisture absorption were cut as per the standards dimensions specified in ASTM. The ASTM D638 standard is used for tensile, ASTM D790 standard for flexural, ASTM D256 standard for impact test.

| Resin used       | LY 556 Epoxy resin |
|------------------|-------------------|
| Reinforcement    | Hibiscus sabdariffa |
| Specimen plate dimension | 300 × 300 × 13 mm |

2.5 Flexural Test

The flexural properties of the specimen is determined by flexural test carried out with ASTM D70 standards. The test was carried out using UTM machine at the rate of 2 mm/min. The overall length of the specimen which can be loaded is 150 mm. the specimens were cut in to 175 × 13 mm × 13 mm. the following equations (1) and (2) are used to calculate the Flexural strength and flexural modulus.

\[
Flexural\ strength = \frac{3Ll}{2wt^2} \text{ in MPa} \quad (1)
\]

\[
Flexural\ Modulus = \frac{ml}{4wt^3} \text{ in MPa} \quad (2)
\]

Where, \(L\) – Maximum applied load in N, \(l\) – Length of the specimen in mm, \(w\) – Width of the specimen in mm, \(t\) – Thickness of the specimen in mm, \(m\) - The slope of the curve in N/mm.

2.6 Tensile test

The research method includes assessment of the tensile properties of specimen reinforced with Roselle fiber using ASTM D638 standard. A computerized test rig is used for the testing procedure, based on the machine specifications the specimen was cut into 50-gauge length, 25 mm width and 13 mm thickness and it is loaded in the testing machine. The load is applied gradually at the constant rate of 5 mm/min. the following equations (3) and (4) were used to calculate the tensile strength and modulus of elasticity. The slope of Stress Vs Strain curvature is used to calculate the modulus of elasticity [20-21].

\[
Tensile\ Strength = \frac{L}{wt} \quad (3)
\]

\[
Modulus\ of\ Elasticity = \frac{\sigma}{\varepsilon} \quad (4)
\]

Where, \(L\) – Maximum applied load in N, \(l\) – Length of the specimen in mm, \(w\) – Width of the specimen in mm, \(\sigma\) – Stress in Pa, \(\varepsilon\) – Strain
2.7 Impact Test

The impact strength of the material is determined using this test. The test is conducted by following ASTM D256 standard. The specimen is prepared in manner with a V notch angle of 45o, 2.5 mm depth, 10 mm thickness, 10 mm breadth and 65 mm length to conduct this test. The specimen is placed vertically and held strongly at the middle line of the notch. Once the hammer is released it collides with the specimen, the energy imbibed by the specimen is noted from the scale. The average value of the seven tested specimen is taken as the impact strength. The following equation (5) is used to calculate the impact strength [22-23].

\[
\text{Impact strength} = \frac{E}{A} \ln \left( \frac{kJ}{m^2} \right)
\]

(5)

where, E – Energy absorbed in J, A – Cross sectional area below the notch

| Table 1. Chemical composition of various natural fibres. |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|
| Species                         | Cellulose (wt%) | Hemi-cellulose (wt%) | Lignin (wt%) | Ash (wt%) |
| Pine (softwood)                 | 40–45           | 25–30            | 26–34         | –             |
| Sisal                           | 63–64           | 12               | 10–14         | –             |
| Hemp                            | 70.2–74.4       | 17.9–22.4        | 3.7–5.7       | –             |
| Bagasse                         | 40–46           | 24.5–29          | 12.5–20       | 1.5–2.4       |
| Bamboo                          | 42.3–49.1       | 24.1–27.7        | 23.8–26.1     | 1.3–2.0       |
| Coir                            | 32–43           | 0.15–0.25        | 40–45         | –             |
| Jute                            | 61–71.5         | 12–20.4          | 11.8–13       | 2             |
| Maple (hardwood)                | 45–50           | 22–30            | 22–30         | –             |
| Groundnut shell                 | 35.7            | 18.7             | 30.2          | 5.9           |
| Kenaf                           | 31–39           | 21.5             | 15–19         | –             |
| Flax                            | 64.0 - 71.9     | 16.7 - 20.6      | 2.0 - 2.2     | –             |
| Roselle                         | 65.49           | 20.46            | 5.41          | 0.53          |

| Table 2. Volume and mass fraction of reinforcement and polymer. |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|
| Specimen                         | Mass% (gram)    | Mass of Hibiscus (gram) | Mass of matrix |
| Hibiscus sabdariffa              | Epoxy resin     | Mass of Hibiscus sabdariffa | Mass of matrix |
| 1                                | 10              | 90              | 22              | 265.15         |
| 2                                | 20              | 80              | 44              | 244.97         |
| 3                                | 30              | 70              | 66              | 216.1          |
| 4                                | 40              | 60              | 88              | 213.6          |
| 5                                | 50              | 50              | 110             | 178.45         |
3. Results and Discussion

The Fig 1 to Fig 3 presents the variations in tensile strength, flexural strength and impact strength of composite board with different combination in volume percentage of Rosselle as filler and LY 566 epoxy as the matrix. From the figures it is observed that the introduction of roselle enhances the mechanical properties. The addition of bio filler results in improvement in the tensile strength upto 40 %. After that, at 50 % it falls down. From this we can conclude the addition of Roselle fiber as filler will reduce the tensile strength beyond 50 %. This is because that the fiber powder in particulate shape cannot withstand the load. The Addition of Roselle more than 50 vol% resulted in decreasing of the tensile properties. This is due to the agglomeration of Roselle in the epoxy matrix, this is clearly understand from SEM images 4 and 5. It was due to the brittleness of the composite material. The addition of filler in the matrix may subdue the necking phenomenon and starts to yield. The increase in properties is due to the addition of filler materials in the composite material [24-25].

![Tensile Strength and Tensile Modulus Graph](image1)

**Figure 1.** Tensile properties of Hibiscus sabdariffa filler reinforced epoxy composite

![Flexural Strength and Flexural Modulus Graph](image2)

**Figure 2.** Flexural properties of Hibiscus sabdariffa filler reinforced epoxy composite

The Fig 2 depicts the variation in the flexural strength with respect to different composition ranges from 10 % to 50 %. The results obtained from the test shows that the flexural strength of the material increases with the increase in the volume percentage of roselle but declines after 40 %. The results obtained from flexural test indicates that, the stiffness of the composite board is improved by addition of this reinforcement material.
The Fig 3 presents the observation made in the impact test, shows the impact of Roselle on the impact strength. Toughness of a substance is termed as the energy absorbed during the fracture when the material is subjected to impact loading. Particulate fillers are generally added to increase the stiffness (modulus) and toughness of the composite materials. When the load is applied, the matrix and particulate fillers are separated which requires energy, this energy required depends on the bonding strength between the filler and matrix material. Upto 20 % addition of filler doesn’t show a significant influence on the impact strength value. But after 30 % the impact strength value increases. This is because of the brittle nature of the material [26].

Figure 4. SEM image of 40 vol % Hibiscus Sabdariffa filler evenly distribution

Figure 5. SEM image of 50 vol % Hibiscus Sabdariffa filler agglomeration
4. Conclusion

In the present work, the effect of various volume fraction of Roselle (Hibiscus sabdariffa) reinforced filler addition in the matrix of epoxy resin on the tensile, flexural and impact analysed. It can be observed that the amalgamation of filler enhances the mechanical properties of composite material to certain extent. It is noted that the 40% volume fraction of Hibiscus sabdariffa filler results in maximum tensile strength. While maximum flexural strength and impact strength are achieved with 30 to 40 volume fraction filler material respectively. However, addition of Roselle (Hibiscus sabdariffa) filler beyond a certain limit resulted in significant drop in mechanical of materials. This is Because of uneven dispersion of filler in epoxy matrix.

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