Mode-I fracture toughness evaluation of bio based short areca fibers reinforced polymer composites

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Abstract. Naturally accessible materials have recently become appealing to researchers and scientists due to their suitability as an ideal reinforcement for polymer composites reinforced with fiber. Low cost, relatively strong mechanical properties, qualities of non-abrasive and biodegradability, exploited as a switch to the standard fiber. This research investigates the effect of areca fiber reinforcement of fracture load and fracture toughness. Epoxy resin used as a matrix material. Type I fracture hardness checks are conducted in a universal servo hydraulic control system. The findings revealed a significant improvement in fracture load values and durability of fracture with improved fibre content.

1. Introduction
Natural fibre-reinforced polymer composites become more relevant as environmental consciousness and compel the industries to look for biodegradable and recyclable materials [1]. Natural fiber comprises numerous ingredients such as cellulose, lignin, pectin, and other products. We have distinctive signature for the inclusion of such elements. The use of natural fibers to reinforce the material in epoxy is therefore a simple and positive approach to boost the mechanical properties of composite materials. Many research on the application of natural fibers coir, hemp, rice husk, jute, bamboo, cotton, wood, etc. as the reinforcements in composites have been mentioned in literature [2]. Composites strengthened by areca / betel nut fiber consider greater benefits in the new production of composite products such as electrical insulation applications [3]. Different materials are manufactured, and flaws are not completely preventable on a regular basis. The presence of faults contributes to the proliferation of cracks and structural fractures. Brittle fracturing produces sudden and devastating failures and may trigger major accidents. It is therefore important to research the actions of a defective substance. Predicting the failure of materials having flaws fracture mechanics has been introduced [4, 5]. Due to their complexity during performance prediction, fracture is one of the most challenging distresses. Heterogeneous structure, nonlinear viscoelastic material characteristics, specific loading conditions, and attachment of the fiber matrix are very problems for using basic research and techniques. In fracture mechanics, essential to consider the basic rules such as energy accumulated below the crack tip reaches the material’s crack resistance, then cracking initiates in the vicinity of the crack tip. Using Linear Elastic Fracture Mechanics (LEFM) principles, a crack initiation begin with the Fracture Plastic Zone (FPZ) near the crack tip is studied [6]. Mode I and Mode II deformation can occur for a cracked part that is subjected to in-plane loading. The broken systems often undergo mixed-mode loading under realistic circumstances, i.e. a Combination of mode I and Mode II. Brittle fracture in mixed mode is one of the most frequent forms of mechanical failure in broken framework built from brittle materials. The structural integrity of the fractured component under mixed loading mode is indeed important [7]. Researchers also recommended various theoretical and experimental approaches for exploring brittle
fracture in mixed fashion. Although experimental fracture studies on individual components are always costly and complicated, researchers tend to perform their experiments on specimens from laboratory. However, under their complex service loading conditions, acceptable fracture parameters are often required to equate the experimental results obtained from the basic laboratory experiments to the fracture case in cracked structures. Suitable research conditions may verify the fracture criteria by conducting a sequence of tests on appropriate test materials [8,9]. For this research, notched semi-circular bending (SCB) test was designed to illustrate the fracture properties of the areca-fibre-reinforced polymer composite. SCB test was initially used to identify the characteristics of fracture resistance. Nowadays more and more studies have used the SCB method to study the susceptibility to cracking [10].

The objective of this study is to fracture characterize that account for the variation in mode-dependent fracture resistance of areca fiber reinforced polymer composites through notched SCB and SCAB test. These tests produced maximum load. Furthermore, the relationship between fracture toughness and different composition were found.

2. Materials and Experimentation methods
To fulfil the objective of this research work, the fracture behaviour areca fiber reinforced polymer composites (AFRPC) manufactured with three different compositions were analysed.

2.1. Materials
Areca is empty fruit bunch Fibers (husk) were obtained from local Farm House near davanagere, Karnataka, India. The Epoxy resin L-12 and the hardener (K6) are supplied by Yuje Enterprises Malleswaram, Bangalore.

2.2. Methods
2.2.1 Fiber extraction
Areca fiber was used to fabricate the composites. About five days, dry areca husk was drenched in deionized water. The process of soaking releases the fibers and these can be easily taken out. Lastly, the fibers were splashed with deionized water and again dried for almost 15 days at room temperature.

2.2.2 Alkali Treatment
First, the areca fibers were processed in a 10% NaOH alkali solution, where the overall solution amount was used. The fibers are kept at room temperature in an alkaline solution for 36 hours. Instead, at room temperature, these fibers were dried for 48 hours to get alkali-treated fibers [11].

2.2.3 Preparation of composites
Volume fraction of fiber is one of the most significant factors that affect the properties of the composite. The randomly dispersed areca husk fibers with epoxy resin for different compositions are used to prepare the composite as shown in table 1. Initially; the mould is refined with wax as releasing agent on the surface to easy abstraction of composite after curing. Epoxy resin is mixed with hardener in a ratio of 10:1 by weight. Methodically this can be mixed with reinforcement areca fiber before filled into mould and compressed at the room temperature in a hydraulic press about 30 minutes [12]. Specimens were removed from the mould after 24 hours of curing in the laboratory at standard atmosphere. The process of fabrication of composite material is as shown in ‘Figure.1’.

Table 1. Composition of Testing Specimens

| Sl.no | Areca Fiber | Epoxy Resin |
|-------|-------------|-------------|
| 1     | 40          | 60          |
| 2     | 50          | 50          |
| 3     | 60          | 40          |
2.3. Fracture toughness test
2.3.1 Semi-circular Bend (SCB) and Semi-circular Arc Bend (SCAB) Test
Semi-circular bend (SCB) specimen configurations are advised by various test standards for the toughness test in mode I, mode II and mixed mode I / II fracture. For the classical SCB specimen, one major problem is related to the practical complications of creating a crack in the specimen. SCAB is also appropriate for mode I, II and mixed-mode experiments and this form of specimen configuration will save more than 50 per cent of the material relative to SCB specimens [12]. The SCB and SCAB test design are seen in ‘Figure 2’.

Figure 1. Fabrication of laminated composite: (a) Mixing of resin with hardener (b) Mixing of areca fibers and resin (c) Hydraulic hot press machine

Figure 2. Standard Specimen Configuration (a) SCB (b) SCAB
Fracture toughness testing is conducted in computerized universal testing machine (UTM) at room temperature. Single notched SCB and SCAB specimens are introduced for fracture experimentation to this end. ‘Figure.3’ shows the geometry of the SCB and SCAB specimen experiment setup. During the tests the failure load data is recorded. All of the test samples quickly fractured with negligible non-linear deformation from the crack tip. It indicates the brittle behaviour of the samples tested on fracture [13]. The toughness of the fracture is measured using the fracture load derived from each test, and the findings are reported.

3. Results and Discussion
Throughout the present study, the toughness of the fracture is calculated for specific composition from the SCB specimen and SCAB specimen with ($\alpha=0^\circ$), and the experimental findings were described in this portion.

3.1. Semi-circular Bend (SCB) Fracture Test
The SCB fracture method was used to obtain the fracture toughness of composite materials reinforced with areca fiber. The SCB fracture test is easy to execute and allows the preparation of test specimens simply through core moulds [14]. A lot of studies that have examined post-failure behaviours related to brittle material, where the failure rate tends to decrease before the separation takes place [15]. Experimental tests are used to determine the fractures toughness for different compositions of composites reinforced with areca fiber.
Observations can be clearly noted from that; Fracture load was highest for 60-40 composition as compare to other compositions. SCB specimens were high fracture load to the increased reinforcements. This was estimated with the greater fracture load, more area to resist the failure of the material [16]. It also shown to have greater fracture toughness values at 60-40 composition, which illustrate the larger reinforcement, is more resistance to the cracking process [14]. It is seen that, as the percentage of reinforcement increases from 40% to 60%, the fracture toughness also increases.

3.2. Semi-circular Arc Bend (SCAB) Fracture Test

The fracture load results found in this research for different compositions of areca fiber reinforced composites are shown in “Figure 6”. The 60-40 composition shows higher value of fracture load of 300N as compare to other two compositions. Specimen with larger reinforcement withstands more loads before fracture and more area to resist the failure of the material. The specimens failing by fracture indicated an increase in strength with increasing fiber composition. Fracture load is used to determine the fracture toughness of different composite material and it is shown in “Figure 7”. It is clear that areca fiber reinforced Composite with 60-40 composition shows highest fracture toughness than the other two composite. It is seen that as the fracture toughness increases with increasing the percentage of reinforcement. Which shows that the larger reinforcement is more resistance to the cracking process [14]. This was also estimated with the greater fracture load, more area to resist the failure of the material [16].

![Fracture Toughness vs. Composition for SCB Specimen](image1)

**Figure 5.** Fracture Toughness vs. Composition for SCB specimens

![Fracture Load vs Composition for SCAB test](image2)

**Figure 6.** Fracture load vs. Composition for SCAB specimens
4. Conclusion
In this study, the effects of different composition on the fracture properties of areca fiber reinforced polymer composites were investigated. A laboratory experiment was conducted to characterize the fracture resistance of AFRP composites with fibre volume percentages that ranged from 40 to 60%. The specimen had higher reinforcement had more significant effect on fracture toughness. The main findings are summarized as follows:

For Semi-circular Bend (SCB) Fracture Test:
Fracture load and fracture toughness increases with increasing reinforcement percentage. The (60–40) composition composite specimens give a failure load of 500 N and fracture toughness of 37.015 MPa√m, which is better than (40–60) and (50-50) composition composites.

For Semi-circular Arc Bend (SCAB) Fracture Test:
Fracture load and fracture toughness increases with increasing reinforcement percentage. The (60–40) composition composite specimens gives a failure load of 300 N and fracture toughness of 29.68 MPa√m, which is better than (40–60) and (50-50) composition composites.

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