Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 13, Special Issue 2, 2025
DOI (Journal): 10.37591/JoPC

https://journals.stmjournals.com/jopc

Research JoPC

Mechanical Property Assessment of Hybrid Fiber Reinforced Composites Through Experimental Research

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Abstract

Natural fibre reinforced composites are gradually taking the place of synthetic fibre composites due to its inexpensive cost, low density, and ease of supply. Furthermore, the addition of some waste materials to composites has remarkable properties that are attracting interest from a wide range of technical domains. Fibre reinforced with glass, carbon, and jute were used to generate hybrid composites. As a filler, different amounts of eggshell powder were mixed with the polymer matrix material. Evaluating the tensile and compressive strengths of hybrid composites at room temperature is crucial to understanding their mechanical characteristics. Tensile strength is the highest stress a material can withstand before breaking when stretched or pulled, and compressive strength is the highest tension a material can withstand when squeezed or compressed before failing. The test findings showed that the characteristics were significantly improved by adding 2% eggshell powder. Glass-based composites gain 35% more compressive strength and 19% more tensile strength when 2% eggshell powder is added. Carbon-based hybrid composites have a 3% increase in tensile strength and a 16% increase in compressive strength. Jute-based composites showed increases of 27% in compressive strength and 4.5% in tensile strength. Eggshell-powered being characteristics such as increase matrix density, enhanced interface bonding, and strain energy absorption therefore significantly increasing tensile and compressive strength with adding into glass fiber. Glass fiber is to be considered as a brittle material. By adding the eggshell powder in carbon and jute-based composite, the tensile and compressive strength may be increased but not more when compared to the glass fiber composite because the response of characters of eggshell powder is better performance in glass fiber composite.

Keywords: Hybrid composites, glass, carbon, eggshell powder, tensile strength, compressive strength

INTRODUCTION

Composites are made of two components: matrix material and reinforcement material. Composites are a mixture of two or more materials that form a single unit of material intended to attain the required qualities. Composite materials are developed with two major components, one is matrix material in large quantity and the second is embedded reinforcement materials in less quantity to increase the properties of matrix material, while the matrix component acts as the body of the composite and discussed mechanical properties of glass rain forced polymer composite materials and its effect of ceiling fan blade [1, 2]. Many composite materials are inherently resistant to corrosion, especially those reinforced with materials like carbon fibers or glass fibers. This feature makes composites ideal for uses where traditional materials might typically degrade when exposed to dampness, chemicals, or extreme weather. Composite materials are known

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Received Date: June 04, 2024
Accepted Date: November 11, 2024
Published Date: January 21, 2025

Citation: H. Madhusudhana Reddy, Bhanodaya Kiran Babu Nadikudi, A. Balaraju. Mechanical Property Assessment of Hybrid Fiber Reinforced Composites Through Experimental Research. Journal of Polymer & Composites. 2025; 13(Special Issue 2): S244–S251p.

for their exceptional strength-to-weight ratio. Composites can store a lot of energy under elastic tension. As a result, they can offer superior strength and rigidity while being significantly lighter than metals like steel or aluminium. All of these qualities combine to make composite materials incredibly versatile and in-demand across a range of industries, including the manufacturing of sports gear, cars, buildings, boats, and aeroplanes. Additionally, composites are fabricated in the required shape and size, this reduces machining operations and leads to reduced production costs [3, 4].

The strength of the composite is based on many factors such as fiber shape and direction, fabrication process, and volume of fibers, theoretically defined as more the volume of fibers more the strength of composites. To enhance the properties of composites, there is a further need for the development of hybrid composites which comprise the different fibers along with the matrix material. In recent days, researchers and designers have been working towards the development of composites with sophisticated mechanical and structural properties for the emerging fields of automotive and aerospace applications [5]. Composite materials hold better properties that can be obtained with carbon fiber, glass fiber, and aramid-reinforced composites with a single monolithic material. and described the mechanical characteristics of epoxy hybrid composites reinforced with carbon fibre. These days, producers and designers worldwide are paying attention to the mechanical behaviour of reinforced composite materials. Before incorporating the high-strength composite into the intended application, make sure it is compatible with other components and systems. Composite materials particularly carbon-epoxy composites are strength-bearing materials that are useful in aerospace like re-entry vehicle structures of missiles, and aircraft structures. Few composites hold less compression to tension strength leads to limited usage in some applications [6]. In recent years there has been a huge development of engineering components using polymer composites with natural fibers, and also usage increased significantly because of its many advantages and eco-friendly [7]. Polymeric-based composites are holding beneficial properties such as high strength, stiffness, high corrosion resistance, and fatigue resistance [8, 9]. This property of composites is mainly due to three elements such as type of reinforcements, polymer, and an interface. In recent years, the use of glass fiber and vinyl ester resin-based composites are being increased in engineering applications. This hybrid combination adds superior properties as compared with the composites made with one kind of fibers. Natural fibers also have challenges, such as variability in properties due to natural sources, susceptibility to moisture absorption, and potential issues with durability and long-term performance in certain environments. Research and development continue to address these challenges and expand the range of applications where natural fibers can be effectively used as substitutes for synthetic fibers in composite materials. Compared to synthetic fibre like carbon or glass fibre, natural fibre like jute, hemp, flax, bamboo, and kenaf have a number of benefits, such as being renewable, biodegradable, inexpensive, and requiring less energy to produce. Because they can also provide strong specific strength and stiffness properties, natural fibre are suitable for a variety of structural and non-structural applications [10]. Some fillers including red mud powder [11], coconut shell powder [12], and eggshell powders [13] are more popular natural fibers. On the other side, calcium carbonate ($CaCO_3$) is an inorganic filler material that being water-repellent and eggshells are a readily and plenty available source of material. Eggshells are mostly composed of calcium carbonate, specifically calcite, a crystalline form of calcium carbonate. This compound gives eggshells their characteristic hardness and strength. In addition to calcium carbonate, eggshells also contain small amounts of proteins and other minerals such as magnesium carbonate, calcium phosphate, and various organic materials. These components aid in the overall structure and makeup of eggshells, safeguarding the developing embryo inside. Chicken eggshell powder is a natural waste material that can replace $CaCO_3$ and also holds less specific density [14]. and also less expensive. Some researchers exploited eggshells as a reinforcement in composites for strengthening purposes [15]. It is also known that these egg shells are used in conjunction with the resin material and also as filler materials that support the reinforcement material and lead to the development of a strong composite. Eggshell material is light in weight and economical and easy to availability, can be used as load-bearing components in the areas of automobiles and some structural applications [16, 17]. Few researchers are working on eggshell usage as reinforcement material in composites to improve mechanical properties. From the available literature, it is found that limited research has been conducted using eggshell powder as a filler material in polymer matrix which includes reinforcement fibers such as glass, carbon, and jute materials.

This work proposes the development of hybrid composites with polymer matrix material with Glass, Carbon, and Jute as reinforcement materials with different percentages of eggshell as filler material and mechanical properties are evaluated. Madhusudhan Reddy H. et.al Experimental investigation of mechanical properties of sisal fiber and rice husk reinforced polymer composite [18] Referred the mechanical property testing. Bala Raju et.al [19, 20] used natural fiber materials also in automobile applications for better durability. In practically, Natural Fiber (Jute, Bamboo) week and lesser stiffness while compared to synthetic fibers because of good tensile strength and also good performance in stress applications. Weight and Density point of view Natural fibers are lightweight and least density respectively when compared the glass fiber and synthetic fibers, and are renewable and biodegradable Durability and endurance are less and good environmental conditions respectively. Also, cheaper cost and good environment-friendly elements [21]. A few of the research papers stated that the experimental for standard testing Consistency in Test Conditions, Reproducibility through Standard Methods, Equipment Calibration and Maintenance, Materials Selection and Preparation, Statistical Confidence, Global Comparison and Traceability, Testing Range and Limits. Was considered only as per ASTM standards for subjected to testing of mechanical properties [22]. From the available literature, it is found that limited research has been conducted using eggshell powder as a filler material in polymer matrix which includes reinforcement fibers such as glass, carbon, and jute materials. This work proposes the development of hybrid composites with polymer matrix material with Glass, Carbon, and Jute as reinforcement materials with different percentages of eggshell as filler material mechanical properties are evaluated and the Impact on mechanical properties increasing in stiffness and strength Durability Curing Process Impact Resistance, Recyclability, and Manufacturing Flexibility [23, 24].

EXPERIMENTAL PROCEDURE

For the development of Glass hybrid composites, Glass fibers are used as reinforcement material, and Epoxy resin is used as matrix material with the proportion 1% and 2% eggshell powder. The egg shells were collected and washed well with water and ensured that the white membrane was removed and then dried naturally. Egg shells were powdered using a kitchen blender to the size of a 90-mesh sieve, this powder consists of tiny and irregular shapes. The hardener used to mix with resin is Tri Ethylene Tetra Amine. The glass fiber mat is 200 grams per square meter and has a density of 2.5 gm/cc used to develop glass composites. The resin and hardener were mixed properly and were subsequently stirred constantly. The glass fiber mats were developed as per size and placed one mat in the mold and resin and a harder mixture is applied on the mat surface with brush uniformly. Next second mat is placed on the first mat after keeping the third mat over the second mat surface and a harder mixture is applied on the mat surface uniformly. The carbon fibers mat is of 200 grams per square meter and density of 1.78 gm/cc used to develop carbon fiber composites. Jute mat of 200 grams per square meter and 2.0 gm/cc density were used to develop Jute hybrid composites. Specimens were sliced according to dimensions as per standard guidelines of ASTM D638 for conducting tensile and compression tests. Specimens were prepared with a length of 60mm, breadth of 12mm, and thickness of 3mm. Three samples of each hybrid composite were prepared at room temperature and tested for compressive and tensile strength using the Universal Testing Machine (UTM). doing mechanical testing, especially compression and tensile testing, with a tensile testing machine (also known as a universal testing machine). This is an overview of the process that was described. These specimens are typically rectangular in shape, depending on whether the test is tensile or compression. The specimen is securely held between the grips of the tensile testing device. For tensile testing, the specimen is frequently positioned so that the grips can separate from one another. During compression testing, the specimen is positioned so that the grips can press against one other. During tensile testing, the machine applies a pulling force, also known as a tensile load, to the specimen. The force is gradually raised until the specimen cracks. During compression testing, the machine applies a compressive force, also called a compression load, on the specimen until it breaks. After testing, the load versus elongation (or stress versus strain) data is analyzed to calculate various mechanical properties of the material. The maximum consumed load and elongation were recorded in the data logger which is connected to the machine. the fractured specimen can be examined to understand the mode of failure, which can provide insights into the material's behavior under stress. Tensile and compression testing are fundamental methods used to characterize the mechanical properties of materials, essential for ensuring quality and performance in engineering applications. To ascertain the tensile and compressive qualities, each test was conducted three times, and the average results were taken into account.

FABRICATION OF COMPOSITE MATERIAL

Hand Layup Process

The hand layup process (Figure.1) for carbon and glass fiber composites is a widely used method due to its versatility and simplicity. Mold: Usually made from fiberglass, metal, or composite materials, depending on the part requirements. Release Agent: Applied to the mold to facilitate easy removal of the finished part. Resin: Typically, a thermosetting resin like polyester, vinyl ester, or epoxy, depending on the mechanical and chemical properties needed. Glass Fiber Reinforcement: Consists of fiberglass mats, cloth, or woven rovings, which provide strength and stiffness to the composite. Rollers and Brushes: Used for resin application and to remove air bubbles. Personal Protective Equipment (PPE): such as gloves, goggles, and respirators to ensure safety when handling chemicals. Low Cost: Minimal investment in equipment and tooling. Versatility: Suitable for producing parts of varying sizes and shapes. Flexibility: Easy to make design changes during production. Skill Dependent: Quality and production rates can be optimized with skilled operators Hand layup remains a preferred method for prototyping, custom parts, and low to medium-volume production where cost-effectiveness and flexibility are priorities.

MATERIAL REQUIRED FOR MANUFACTURING

Eggshells are washed with lukewarm water. Sometimes tap water is also used fine as long as it's potable, meaning safe for drinking. However, if you have concerns about the quality of your tap water, you could use filtered or bottled water instead. After washing the eggshell, there may be some impurities are present, these could include bacteria, dirt from the egg itself. The developed composites are shown in Figure 2 (Before trimming) and Figure 3 (After trimming) respectively. Table 1 shows materials for fabrication of composites.

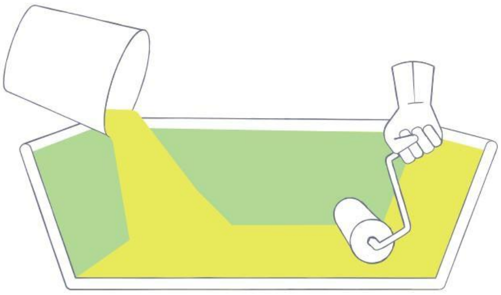

Figure 1. Hand layup process.

(https://compositeslab.com/composites-manufacturing-processes/closed-molding/index.html)

Table 1. Material required for manufacturing of Composite materials.

S N.	Material	Quantity
1	Hardener HY-556	200gms
2	Glass Fiber	4 m
3	Gloves	5 pairs
4	Epoxy Resin LY-556	2000gms
5	Stirring Rod	1
6	Carbon Fiber	4 m
7	Teflon Sheets	10
8	Measuring Jar	1
9	Egg Shell Powder	30g
10	Jute Fiber	4m
11	Portable Weighing Machine	1

Figure 2. Composite materials before trimming.

Figure 3. Composite material after trimming.

RESULTS AND DISCUSSIONS

Tensile strength is the highest stress a material can withstand before breaking when stretched or pulled, and 4.5% in tensile strength as shown in Table 2. Eggshell-powered being characteristics such as increase matrix density, enhanced interface bonding, and strain energy absorption therefore significantly increasing tensile with adding into glass fiber. Glass fiber is to be considered as a brittle material. By adding the eggshell powder in carbon and jute-based composite, the tensile increased but not more when compared to the glass fiber composite19% more tensile strength when 2% eggshell powder is added. because the response of characters of eggshell powder is better performance in glass fiber composite. and Carbon-based hybrid composites have a 3% increase in tensile strength in figure 4.

Table 2. Tensile Strength results of % of eggshell in glass carbon and jute based composite material G-Glass fiber C-carbon fiber J-Jute fiber.

S N.	Composition	%of eggshell	Tensile strength (N/mm^2)
1	GGCCGG	1	162.376
2	CCGGCC	1	192.339
3	JJGGJJ	1	116.851
4	GGCCGG	2	195.752
5	CCGGCC	2	196.563
6	JJGGJJ	2	119.435

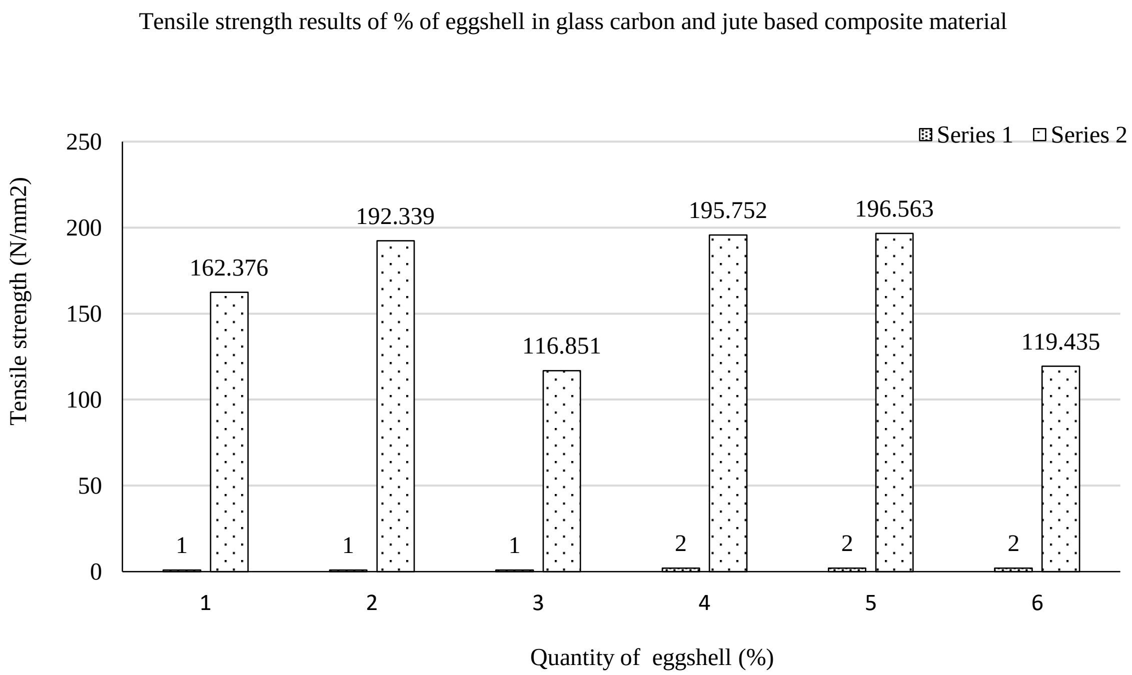

Figure 4. Tensile strength vs Different compositions (Where 1= GGCCGG, 2 = CCGGCC, 3 = JJGGJJ).

Table 3. Compression Strength results of % of eggshell in glass carbon and jute based composite material G-Glass fiber C-carbon fiber J-Jute fiber

S N.	Composition	Quantity of eggshell (%)	Compression strength(N/mm^{2s})
1	GGCCGG	1	715.00
2	CCGGCC	1	836.10
3	JJGGJJ	1	517.43
4	GGCCGG	2	966.800
5	CCGGCC	2	966.860
6	JJGGJJ	2	652.265

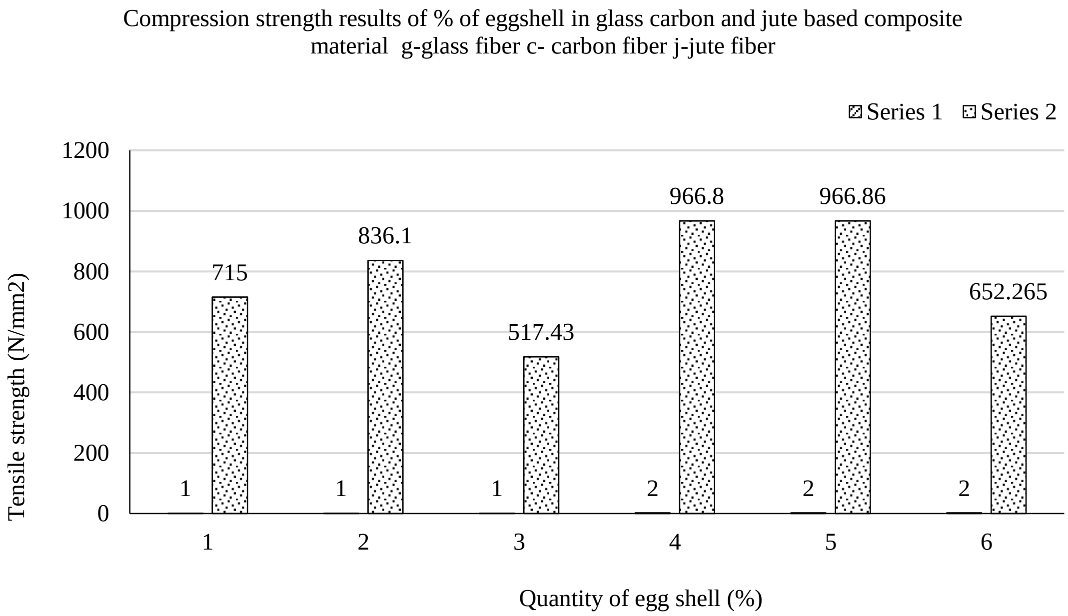

Figure 5. Compression strength vs different eggshell powder compositions (1 = GGCCGG, 2 = CCGGCC, 3 = JJGGJJ).

The test findings showed that the characteristics were significantly improved by adding 2% eggshell powder in Table 3. Glass-based composites gain 35% more compressive strength 16% increase in compressive strength. Compressive strength is the highest tension a material can withstand when squeezed or compressed before failing. Jute-based composites showed increases of 27% in compressive strength in Figure 5

CONCLUSIONS

Different fiber-reinforced composites were fabricated successfully using glass, carbon, and Jute as reinforced materials with the addition of 1% and 2% eggshell in a hybrid combination. The carbon fiber reinforced composites show better tensile properties and there was a significant enhancement in the tensile strength after increasing the eggshell weight from 1 to 2%. Glass and jute fiber composites show enhancement is about 5 to 6MPa. For all hybrid reinforced composites, a better percentage of eggshell powder was found to be 2%. By increasing the percentage of eggshell from 1 to 2%, the tensile strength increased by 19% for Glass-based composites, tensile strength increased by 3% for Carbon-based composites and tensile strength increased by 4.5% for jute-based composites. In the case of compressive strength, there is an improvement of 35% when increasing the percentage of eggshell material from 1 to 2%. Similarly, an improvement of 16% and 27% were achieved in the case of Carbon and Jute composites respectively. Composites were able to achieve higher tensile and compressive strengths due to the consistent distribution of filler particles in the matrix material and the enhanced fiber-matrix adhesion with a high proportion of eggshell material.

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