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Experimental Investigations on the Mechanical Properties of Coconut Coir and Egg Shell Powder Polymer Composites

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ABSTRACT

In recent days most of the automotive parts are manufactured with different materials which will increase the weight of the vehicle and the materials also cannot be recycled. But with the European union and Asian countries stringent norms on automotive end life i.e the parts should be recycled. This made the researchers to use natural fibers in composite materials. With their low cost, low density, stiffness, high specific strength and biodegradable characteristics, they are considered as perfect replacement for conventional fibers. This has resulted in creation of more awareness about the use of natural fibers based materials mainly composites. The properties of the composites mainly depend on the interfacial adhesion between the matrix and the fibers. The present study aims at the mechanical properties namely tensile strength, flexural strength and impact strength of the composites. In the present work the composite is produced with good compressive strength (Egg shell) and tensile strength (coconut coir) materials and is further tested for various mechanical properties. The results indicated that these composites are very good for automotive applications.

Introduction to natural composites

Many of our automotive applications require materials with different combination of properties that cannot be met by the conventional metal alloys. These conventional metal alloys are neither degradable nor recycled. So, now-a-days these are all replaced by composites. Natural fiber composites are attractive to industry because of their low density and ecological advantages, non-carcinogenic and bio-degradable nature over conventional composites. These composites are having major applications in aerospace, transportation, construction, sports, packaging etc. Besides good corrosion resistance, composite materials exhibit good resistant to extreme temperatures and wear especially in industrial sectors. The fiber reinforced polymer (FRP) is a composite material with high strength fibers such as glass, aramid and carbon [2]. Normally the polymers are classified into thermoplastics and thermo settings. The most commonly used thermoplastics are poly vinyl chloride (PVC), while epoxy resins are the commonly used thermo settings. Now-a-days this epoxy resin attracted many researchers due to their advantages over the conventional fibers like glass and carbon fibers [4].

Composite materials (composites) are made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure. Generally these composites are made of matrix and reinforced materials. The matrix material supports the reinforcement materials by maintaining their relative positions. The reinforcements impart special mechanical and physical properties to the matrix material. Depending upon the composition of these two constituents in the composites the strength of the material will vary [3, 6].

So the designer of the automotive products can choose an optimum combination of these composites for their requirements.

The role of matrix in a fiber-reinforced composites are (i) To keep the fibers in place (ii) To transfer stresses between the fibers (iii) To provide a barrier against an adverse environment such as chemicals and moisture (iv) To protect the surface of the fibers from mechanical degradation. Fibers are the principal constituents in a fiber -reinforced composite material They occupy the largest volume fraction in a composite laminate and share the major portion of the load acting on a composite structure. So for particular application selection of fiber type is important because it influences the characteristics of the composite laminate like density, strength, conductivity and cost. Natural fibers such as banana, cotton, coir, sisal, hemp, egg shell and jute have attracted the scientists and technologists for the various applications [4]. However, moisture content in the fibers can be removed by the chemical treatment to modify the fiber surface.

Harinth reddy et al [1] Investigated coir dust reinforced epoxy matrix composites of different compositions. The abrasive wear properties of the composites were examined in dry conditions at different speed and load conditions on a pin-on-disc machine. The experimental results shown that, the abrasive wear resistance of the composite depends on the coir dust concentration, sliding distance and applied normal load. Slate et al, [2] investigated mechanical properties of coir fiber reinforced cement sand mortar. They tested two different design mixes (cement sand ratio by weight) with and without fibers. It was found that compressive and flexural strengths were increased in case of fiber reinforced mortar as compared to that of plain mortar for both mix design with all fiber contents.

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However, a decrease in strength of mortar was also observed with an increase in fiber content. Sabu Thomas et al [3] investigated the effect of chemical modification, loading and orientation of fiber. In this study Interfacial adhesion between coir and natural rubber (NR) was improved by treatment of the coir fibers with alkali (sodium hydroxide and sodium carbonate) and NR solution, and by the incorporation of HRH/RH bonding systems. Composites containing 10 mm long coir fibers were vulcanized at 150°C according to their respective cure times. Green strength measurements were carried out to measure the extent of fiber orientation. Misra et al [4] investigated fire retardant coir epoxy micro-composites. The coir fiber is treated with saturated bromine water for increasing the electrical properties and then mixed with stannous chloride solution for improving the fire retardant properties only 5% of fire retardant filler reduces the smoke density by 25%. The mechanical properties of the composites were not affected much after the incorporation of fillers. Almeida et al [5] investigated the structural and mechanical properties of coir fiber/polyester composites. Composites prepared with two moulding pressures and with amounts of coir fiber up to 80 wt. % were fabricated. Up to 50 wt. % of fiber, rigid composites were obtained. For amounts of fiber higher than this figure, the composites performed like more flexible agglomerates. Chanakan Asasutjarit et al. [6] studied the effects of pre-treatment of coir fiber for manufacturing coir-based green composites. And then physical, mechanical and thermal characteristics of these composites were analysed. Surface characterizations of the un pre-treated and pre-treated coir fiber were investigated from scanning electron microscopy (SEM) studies. It revealed that there is an improved adhesion between fiber and matrix in the case of pre-treated coir. SEM investigations confirm that the increase in properties is caused by improved fiber-matrix adhesion. A. Bensely et al [7] investigated the mechanical properties of coir fiber composites. In the present work, coir composites are developed and their mechanical properties are evaluated. Scanning electron micrographs obtained from fractured surfaces were used for a qualitative evaluation of the interfacial properties of coir/epoxy and compared with glass fiber epoxy. These results indicate that coir can be used as a potential reinforcing material for making low load bearing thermoplastic composites. Sarocha Charoenvai et al [8] investigated the mechanical properties of coir based green composites. The changes in the proportion of chemical composition and morphological properties of coir fibers with different coir pre-treatment condition were discussed. It is observed that the mechanical properties of coir-based green composites; modulus of rupture and internal bond, increase as a result of chemical composition modification and surface modification. Scanning electron microscopy (SEM) investigations show that surface modifications improve the fiber/matrix adhesion. Abrahams P. Mwasha1 et al [9] investigated the time dependent behaviour of basal-reinforced embankments erected on soft ground using biodegradable geo textiles, coir fiber, derived from coconuts, as reinforcing materials. An analytical model for soil reinforcement, which incorporates changes of foundation soil strength over time due to consolidation, is analyzed using the GEO5 slope stability computer software. and calculated the initial strength required to achieve a specified factor of safety. Cervalho et al [10] studied the effect of chemical modification in on the effect of coconut fiber composites lingo cellulose fibers from green coconut fruit were treated with alkaline solution (NAOH 10%m/v) and then bleached with sodium chlorite and acetic acid. Alkali treated bleached fibers were mixes with high impact strength polystyrene (HPIS) and placed in injector chamber to obtain the specimen for tensile test. Specimens were tested in tensile mode and fracture surfaces of composites were analysed by scanning electron microscope and x-ray diffraction. The results showed that the addition of 30% alkali-treated and bleached fibers reinforced in HPIS matrix provide considerable change in mechanical properties in comparison of pure. Sanjay Kindo et al [11] investigated development and characterization of a new set of natural fiber based polymer composites consisting of coconut coir as reinforcement and epoxy resin. The newly developed composites are characterized with respect to their mechanical characteristics. Experiments are carried out to study the effect of fiber length on mechanical behaviour of these epoxy based polymer composites. In the present work, coir composites are developed and their mechanical properties are evaluated. Scanning electron micrographs obtained from fractured surfaces were used for a qualitative evaluation of the interfacial properties of coir-epoxy. These results indicate that coir can be used as a potential reinforcing material for many structural and non-structural applications. A.zuradia et al [12] investigated the effect of fiber length on mechanical properties of coir fibber reinforced cement-album composites. The experiment presented that the increasing the length of fiber increases the flexural strength. But incorporation of long fiber into the cement past reduced the workability thus introduced voids result in low density in fact water absorption and water content also increased. The present paper reports to develop a polymer matrix composite (Epoxy- resin) using coconut coir powder and egg shell powder in different volume and evaluate its tensile strength, flexural property and hydrophilic behaviour along with engineering application of resulting composites.

Materials and Methods

These composite materials can be prepared by different methods such as Manual Lay-Up Method**,** Automated Lay-Up Method**,** Spray-Up Method**,** Filament Winding Method **and** Pultrusion Method**.** Among all the methods manual lay-up method is best and hence it is followed.

Manual Lay-Up Method

Manual lay-up involves cutting the reinforcement material to size using a variety of hand and power-operated devices. These cut pieces are then impregnated with wet matrix material, and laid over a mould surface that has been coated with a release agent and then typically a resin gel-coat. The impregnated reinforcement material is then hand-rolled to ensure uniform distribution and to remove trapped air. More reinforcement material is added until the required part thickness has been built-up. Manual lay-up can also be performed using pre impregnated reinforcement material, called 'prepreg'. The use of prepreg material eliminates separate handling of the reinforcement and resin, and can improve part quality by providing more consistent control of reinforcement and resin contents. Prepreg must be kept refrigerated prior to use, however, to prevent premature curing.

In this composite material, we are using coconut coir fiber and eggshell powder as reinforcing element for preparation. Because the coir fiber has large tensile strength and eggshell powder has large compression strength. The process of preparation of composite material is majorly combination of below two things.

1. Preparation of composite materials
2. Testing of composite materials

Preparation of Egg Shel Powder

A large number of egg shells are collected from a local seller. These collected egg shells are exposed to sunlight for drying process. After drying egg shells were dipped into the sodium carbonate solution for cleaning purpose. After cleaning the inner layer which is present inside the shells was removed. These were ready for the preparation of egg shell powder. These collected shells were converted in to powder form in a local mill up to 150 microns grain size

Fig 1. Preparation of Egg shell Powder by hand layup technique.

Preparation of Coconut Coir Powder

Coconuts were collected from local vendors to prepare coconut coir fiber powder. These coconuts contain two layers one is Exocarp and another one is called Mesocarp. The green layer which is present on the top of the coconut is called Exocarp and the fiber type layer which is present inside the green layer is called Mesocarp. Inside the coconut some meet will be available and is called as Endo sperm. In the preparation of coconut coir powder first the dry coconut coir fiber from coconut is removed. Now these coconut fibers are hammered for the removing of waste particles in fiber. Then these fibers are sent to the machining process for the coconut coir powder. The machining process and seaving process were continued until a grain size 150 microns was obtained.

Fig 2. Preparation of Coconut Coir Powder By Hand Lay-Up Technique.

Method of Manufacturing Specimen

For the preparation of composites the egg shell powder and coconut coir powder are mixed in the proportion of different ratios 50:50, 40:60, 30:70, 20:80, 10:90. Initially epoxy resin and hardener were mixed together based on the weight ratio to form a matrix Materials. The sequence of operations for preparation of composite material as follows.

Identification of raw materials
↓
Selection of die to prepare composite material
↓
collection of coconut coir & egg shell powder
↓
dry the raw materials in sunlight for about 12hours
↓
Clean the raw materials
[for egg shell by adding NaOH solution in 2hrs]
↓
Powdered the raw materials by using grinding machine
↓
Prepare the composite material
[by taking both materials with various ratios and add epoxy hardener to get good mixture at room temperature]
↓
The wet composite mixture was inserted into the die and close the die with help of threads
↓
Keep the die at room temperature in 24 hours for drying
↓
After drying composite material is removed from the dies
↓
Cut and finish the composite material
↓
After cutting, it will sent to the inspection section
↓
Check the specimen as per ASTM standards
↓
Test Specimens

Fig 3. Lay-out for Preparation of composite materials.

Testing of Composite Materials

The prepared composite material specimens are tested by using testing machines. The tensile specimens are tested by universal testing machine (UTM), Compression specimens are tested by compression testing machine and the impact specimens are tested by impact testing machine. Apply the load on the material specimens and record the values at which the specimen broken. Collect the tested values of composite material specimens with their related ratios. The tests were conducted with the following machines.

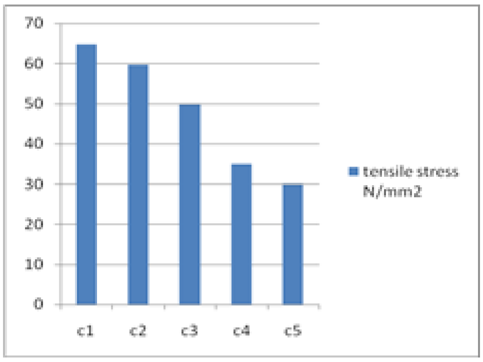

Fig. 4.a) UTM b) Impact testing machine

Results and Discussion

The composite materials with combination of coconut coir coir and egg shell with epoxy resin and hardener and they tested to evaluate the mechanical properties and they represented below.

Tensile Test Properties

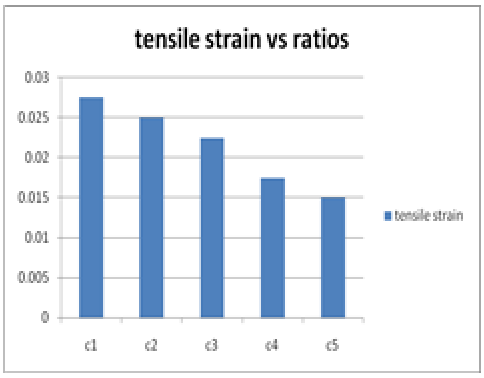
The tensile strength of composite material is depends upon the fiber percentage. In this below graph shows decreasing of tensile strength with decreasing coir percentage.



Graph 4. Variation of Tensile Strength for Different Mixtures Of Composite Materials.

The tensile strength of the composite depends on the quantity and quality of fiber used. The Graph 4 exhibits the variation of tensile strength with different composite ratios for the maximum peak loads. The ratio C1 has largest tensile stress of 64.69 N/ mm^2 and C5 has lowest tensile strength of 29.86 N/ $mm^{2.}$ The tensile strength of composite is uniformly decreasing from C1 to C5. It is evident that with the increase of coconut coir percentage, the tensile strength of the composite is gradually increases. This is because of surface and chemical modification which improve the adhesive property between the two materials. This further made the better dispersion of fiber and interaction between them. Therefore it indicates that the chemical treatment of the fiber significantly increases the bonding strength and further tensile strength.

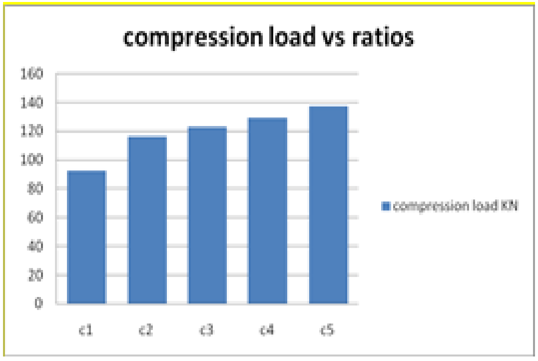
Tensile Strain



Graph 5. Variation of Tensile Strain for Different Mixtures Of Composite Materials.

The variation of tensile strain with the different ratios of composite material is evident from the graph 5. This reveals the material property under tensile load. As the percentage of coconut coir powder is increasing the tensile properties are also increasing. This is due to its bonding strength. From the graph it is observed that the ratio C5 has the lowest tensile strain of 0.015. The ratio C1 has 45.45% higher tensile strain than C1. All other values are in between these extremes.

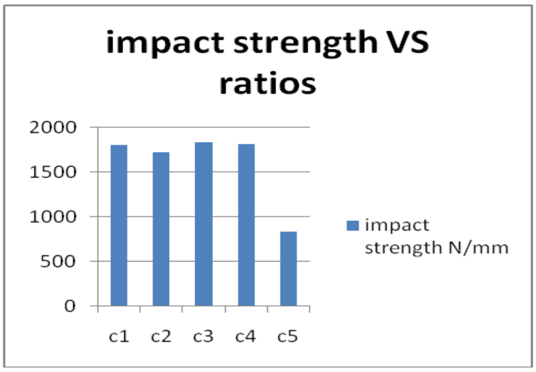
Compression Test



Graph 6. Variation Of Compression Load For Different Mixtures of Composite Materials

The compression strength of the composite mainly depends on the type of natural fiber content used and increases with the amount of fiber content. The compressive strength variation with the percentage of composite material is illustrated in the above graph 6. It is evident from the graph that the composite material C5 is having more compressive strength. As the egg shell powder content is increasing the composites compressive strength will also increase. It is observed from the graph that the material C5 shows maximum compressive strength of 137.5 KN. All other composites strength is in between C1 to C5. The treatment of the fiber modified the surface energy and the tension of the fiber and further improves the molecular chain reaction.

Impact Test



Graph 7. Variation of Impact Strength For Different Mixtures of Composite Materials.

The variation of impact strength of the composites with the ratios of material is shown in the graph 7. With the results it is concluded that the introduction of fiber content increases the impact strength. Due to the chemical treatment of the composites of reinforced surface with bonding material, the bonding strength between fiber and eggshell power is improved. Individually the bonding strength of the egg shell power or coconut coir power is less. But the improvement of bonding strength with the combination of these two materials is higher.The impact strength with the ratio C3 is more i.e 1826.39 N/ mm and minimum with the ratio C5. So it is concluded that with C3 both coir and eggshell have moderate amount.

Conclusion

The mechanical behaviour of the CE composite material has been estimated in the present work. The materials of CE composite had taken in different ratios are mixed with resin and hardener and made into geometrical shapes. These have been tested experimentally for impact, compression and tensile tests. The results found as high compression test for C5 composition, because eggshell have good compressive strength. For impact test C3 composition has good impact strength the reason is both composites have large quantity. For tensile test C1 composition has good tensile strength and strain, because coconut coir fiber have good tensile properties. So from this experiment we conclude that the tensile strength of composite depend on coir fiber and compression strength of composite depend on eggshell quantity and also impact strength of composite depend on both composites.

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