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INVESTIGATION ON MECHANICAL BEHAVIOUR OF CALCIUM CARBONATE AND GROUNDNUT SHELL FILLER ADDED COCOS NUCIFERA FIBER REINFORCED POLYESTER COMPOSITES

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ABSTRACT

Natural fiber-reinforced composites have become superior materials due to their potential to replace synthetic fibers, because of their low density, lightweight, low-cost biodegradability, and high specific strength. This study finds out the mechanical properties of coir fiber-reinforced polyester matrix composites with the addition of filler content. The composites were fabricated using a compression molding machine with a dimension of (300x300x3) mm. Totally 6 laminates were fabricated with variations in fiber and filler content. The fabricated composites were cut the different types of ASTM standards. The mechanical properties of the calcium carbonate and groundnut shell-filler added coconut fiber-reinforced polyester composites were studied. The maximum tensile, flexural, and impact strength was achieved by 29.6 MPa, 56.8 MPa, and 34.8 kJ/m^2 respectively. The addition of fillers in composite increases the mechanical strength. Fractography studies were used to analyze the fracture behaviour in fiber-reinforced composites. Coir fiber-reinforced composite materials are applicable for low load-bearing applications.

Keywords: coir fiber, polyester, calcium carbonate, groundnut shell.

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1. INTRODUCTION

Natural fiber is obtained from natural plants, animals, fruits and so on. Many natural fibers are occurred such as Jute, sisal, hemp, Baggase, Flax, kenaf, banana, Luffa, roselle, areca, corn, coir etc., [1-4] The major advantage of natural fiber is abundantly available in this world, cheap, low density, lightweight and Bio degradability. Natural fiber is very efficient and less cost than manmade fiber. Mostly the density is less than 2 kg/m^2 and 3.5 kg/m^2 in the natural fiber and synthetic fiber respectively. Extracted fibers have only limited strength, if increase the strength, chemical treatment is mandatory. Different types of chemical treatments are used in fiber-reinforced composite materials like silane, sodium hydroxide, calcium hydroxide, potassium hydroxide, peroxide treatment and so on [5, 6]. While treating the natural fibers completely remove the surface dirties, oil, wax and unwanted sheaths [7]. Treated fiber is good interfacial bonding and adhesive property is high than the untreated fiber, it is very useful to the increase the mechanical performance [8, 9]. Different type of resins are occurred such as vinyl ester, epoxy, polyester, poly propylene, formaldehyde etc. [10-12] any natural or synthetic fillers were added in the composite to escalation the strength and neglect the voids. Polymer matrix composites are mostly fabricated in hand layup and compression moulding process [13-14]. Fiber reinforced composite materials used in many applications such as structural, construction, sports equipments, food products, Automobile parts etc. [15-19].

Ramesh *et al.* investigated the mechanical behaviour of hybrid (kenaf - glass) fiber reinforced polymer matrix composites were using finite element analysis. The 90° orientation achieved the maximum tensile, flexural; impact strength achieved by 69.86 MPa, 162.56 MPa and 6.6 J respectively [20]. Sabarinathan and Sutharsan, M *et al* studied the various weight percentage of brown alumina fillers (0, 5, 10, 15 and 20) loading on thermal, hygro thermal and mechanical behaviour of glass fiber reinforced polymer matrix composite [21, 22].

Madhu and Saravanakumar *et al* reviewed the characterization and synthesis of various natural fibers and focused the physical and chemical properties [23, 24]. Natinee and Saravanakumar, S et al findings of the FTIR and SEM analysis reveal that alkali treatment increases surface area and roughness, which improves the mechanical interlocking of the fibre and natural rubber [25-28]. In this investigation reinforcement and matrix used in green husk coir fiber & polyester resin. In addition of fillers calcium carbonate and groundnut shell utilized while making the composite. 6 different types of laminate fabricated with the help of compression molding machine and analysed the mechanical behaviours in the fiber reinforced polymer matrix composites.

2. MATERIALS AND METHODS

2.1 Collection of Reinforcement and Matrix

The botanical name for the coconut is cocos nucifera. Coir fibers have been extracted from the coconut fruit using the de-husking machine. After collected the complex-shaped fiber is removed from the coconut, then it is passed to the fibering machine, it is the husk is split into smaller bits. In this materials were watered for 2 to 3 days

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because the unnecessary particles were removed and then given to the beater machine, finally get the coir fiber. Polymers usually act as good binders for the reinforcement and also transfer the load entire laminate system. Unsaturated polyester resin is selected for the matrix because of its availability, low cost, and good compatibility. Accelerator and catalyst were used in the entire work.

Figure-1. Photographic image of the Coir fiber.

Figure-2. Photographic image of the polyester resin.

Table-1. Mechanical properties of unsaturated polyester resin.

Properties	Value
Density	1320kg/m^3
Poisson's Ratio	0.32
Young's Modulus	1340 Kg /m3
Thermal Expansion	0.21 W/m°C
Thermal Conductivity	0.21W/m ^{0}C

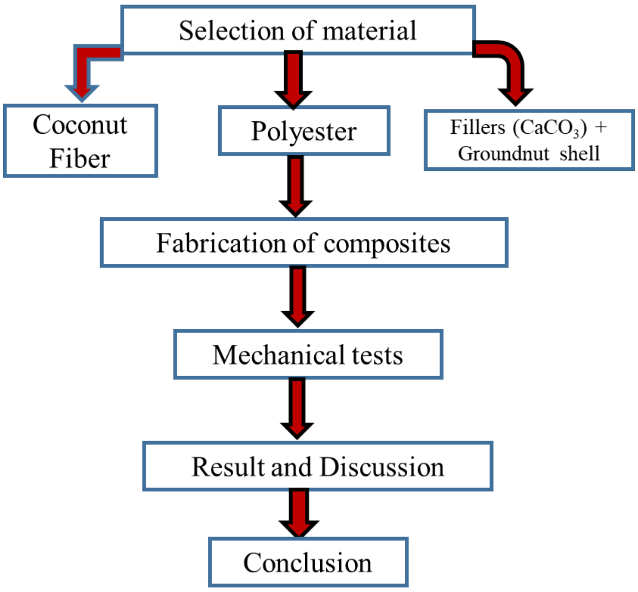

Figure-3. Methodology of fabrication of composites.

2.2 Fillers ($CaCO_3$) and Ground Nutshell

The fillers are used calcium carbonate and ground nutshell. Calcium carbonate purchased by Go green products, Chennai, Tamilnadu. Groundnut shell collected to the farmers**.** While adding the fillers in composites various benefits revealed in composite such as abrasion resistance, heat resistance, stability, viscosity, fabrication mobility and avoiding the void. The density of $CaCO_3$ and Ground nutshell is 2.71 g/cm^3 and 2.45 g/cm^3.

Figure-4. Image of the calcium carbonate.

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Figure-5. Image of the groundnut shell.

2.3 Fabrication of Composites

Fabrication of composites using Compression molding machine with the mold dimension of (300 x 300 x 3) mm. Temperature - 50°C and Pressure - 2.5 Mpa given to the machine. Totally 6 laminates were fabricated with the variations of filler content (0%, 2%, 4&, 6%, 8%, 10%). The resin, accelerator and catalyst were mixing ratio of 100 : 2 : 1. The fiber content 40 %, and the matrix content was 60 % in weight based taken for the fabrication of composite.

Table-2. Fabrication of composite laminates.

S. No	Sample Identification	Resin (%)	Fiber (%)	Filler content (%)
1	S1	60	40	0
2	S2	60	38	2
3	S3	60	36	4
4	S4	60	34	6
5	S5	60	32	8
6	S6	60	30	10

2.4 Tensile Test

The tensile test samples were prepared of a dimension of (165 x 25 x 3) mm rendering to the standard of ASTM D 3039. The crosshead speed of the tensile testing machine was 5 mm/min, and the internal load was applied until the breakage of the material. Five sets of samples were taken for the analysis of the tensile test.

2.5 Flexural Test

The three-point bending flexural test specimens were prepared using ASTM D 790-07 standard with the dimension of (127 x 12.7 x 3) mm. The crosshead speed was 5 mm/min and the span length of 50 mm for entire samples. Five sets of specimens were taken for the analysis, and the corresponding average values were noted down. The following equation is calculated by flexural strength.

$$\sigma = \frac{3pl}{2bt^2} \quad (1)$$

In equation (1), p - load, l - length of span, b - width, t - thickness of the composite specimens.

2.6 Impact Test

The impact test samples were prepared using ASTM D 256-06 standard with the dimension of (62.5 x 6.25 x 3) mm. The Charpy impact test apparatus (Make: ATS FAAR, Model: 16.1 and capacity of up to 25 J) was carried out for testing the samples. Five sets of specimens were taken for the analysis, and the corresponding average values were noted down.

3. RESULT AND DISCUSSIONS

3.1 Tensile Strength of the ($CaCO_3$ + Groundnut Shell Coir-Polyester)

Figure 6 shows that the tensile strength values of $CaCO_3$ + Groundnut shell Coir-Polyester. The maximum tensile strength was 29.6 MPa achieved by 36% of fiber and filler content 4% in the $CaCO_3$ + Groundnut shell Coir- Polyester composites due to effective stress transfer takes place between filler and matrix [3]. The minimum value was 25.2 MPa obtained in 30 % of fiber and 10% filler added in composites.

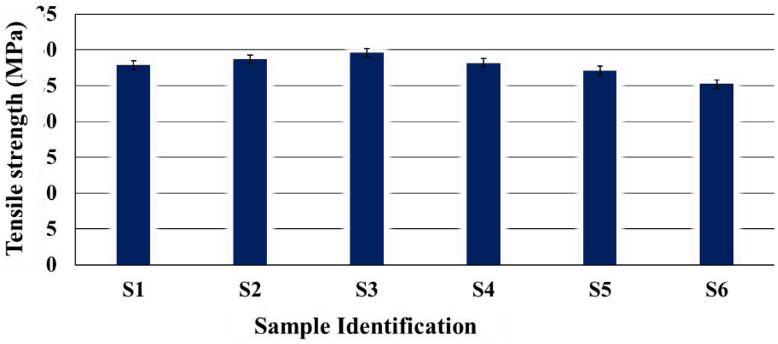


Figure-6. Effect of the tensile strength (CaCO3 + Groundnut shell Coir-Polyester).

3.2 Flexural Strength of the ($CaCO_3$ + Groundnut Shell Coir-Polyester)

Figure-7 shows the flexural strength values of $CaCO_3$ + Groundnut shell Coir-Polyester. The maximum flexural strength was 76.8 MPa achieved by 36% of fiber and filler content 4% in the CaCO3 + Groundnut shell Coir-Polyester composites. The addition of filler contents may reduces the free spaces and improve the tensile property. The minimum value was 54.7 MPa enhanced in 30% of fiber and 10% filler added in composites due to high amount of filler influenced by decrease the flexural strength it may be due to poor adhesive bonding between reinforcement and matrix.

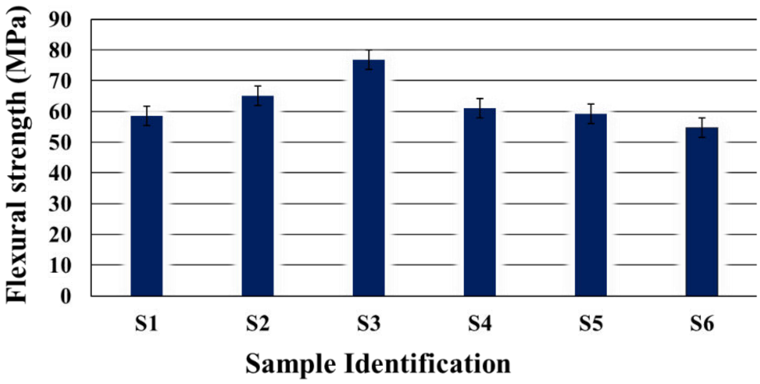


Figure-7. Effect of the flexural strength (CaCO3 + Groundnut shell Coir-Polyester).

3.3 Impact Strength of the ($CaCO_3$ + Groundnut Shell Coir-Polyester)

Figure-8 shows the impact strength values of $CaCO_3$ + Groundnut shell Coir-Polyester. The maximum impact strength was 34.8 (kJ/m^2) achieved by 38% of fiber and filler content 2% in the CaCO3 + Groundnut shell Coir-Polyester composites. The minimum strength was 24.2 (kJ/m^2) attained in 30% of fiber and 10% of filler added in composites. The more amount of filler added decrease the stiffness and hardness of the composite. The decrease in impact properties cannot be attributed to the dispersion of filler.

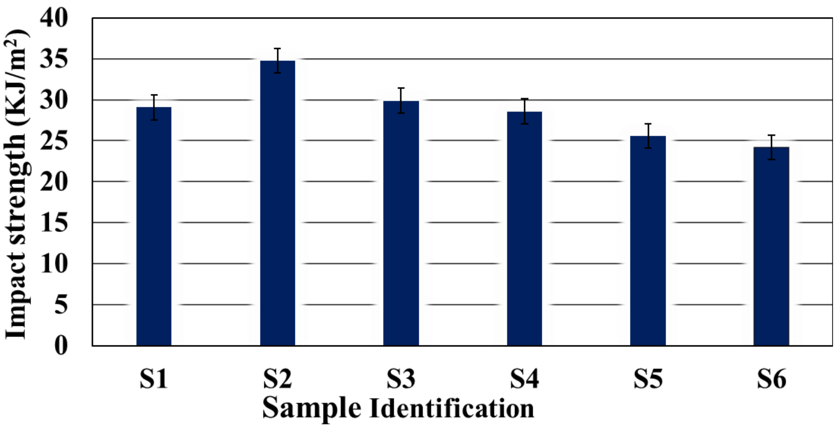


Figure-8. Effect of the impact strength (CaCO3 + Groundnut shell Coir-Polyester)

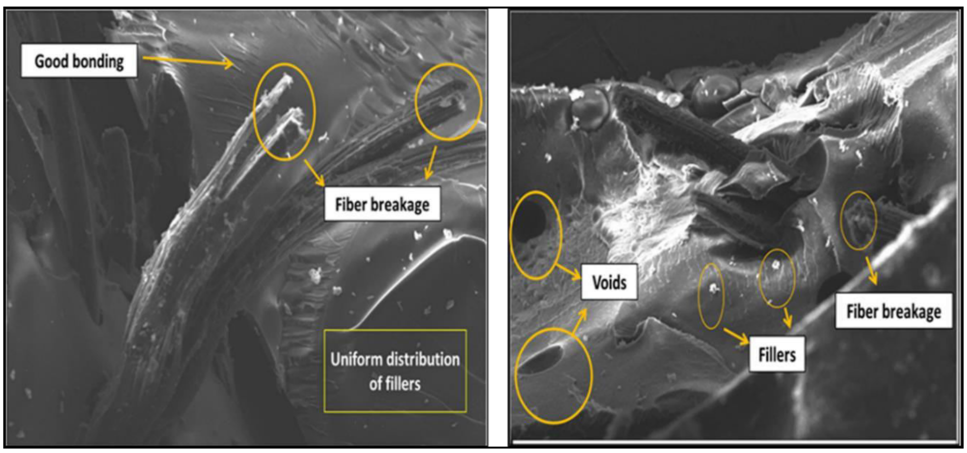
Table-3. Mechanical behaviors of the CaCO3 + groundnut shell added Coir-Polyester composites.

Run	Sample identification	Resin (%)	Fiber (%)	Filler content (%)	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (kJ/m^2)
1	S1	60	40	0	27.9	58.6	29.1
2	S2	60	38	2	28.7	65.2	34.8
3	S3	60	36	4	29.6	76.8	29.9
4	S4	60	34	6	28.2	61.1	28.6
5	S5	60	32	8	27.1	59.2	25.6
6	S6	60	30	10	25.2	54.7	24.2

3.4 Scanning Electron Microscope

3.4.1 Micrograph analysis of tensile fractured specimen

SEM images 9 (a, b) show micro inference on fractured surfaces of the tensile sample. It evaluated the bonding between the fiber and matrix. Fig (a) 36% of fiber and 4% of filled added composite materials. From the micrograph fillers play a minor role in tensile strength, which is uniformly distributed and good bonding occurs in overall composite. Fiber breakage and voids are clearly shown due to the load-carrying capacity of the composite. No fiber pull-out is shown in tensile fractured image, which shows good interfacial bonding with the reinforcement and matrix.



(a) (b)

Figure-9. Micro inference on fractured surfaces of the tensile sample.

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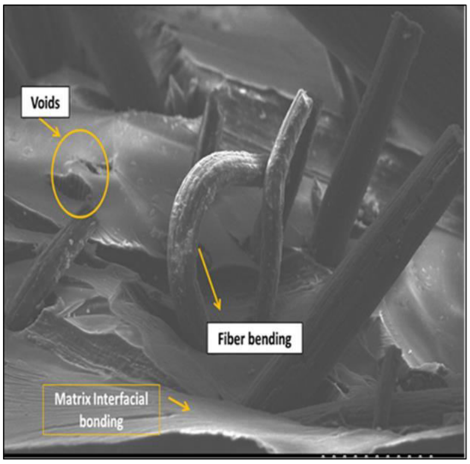
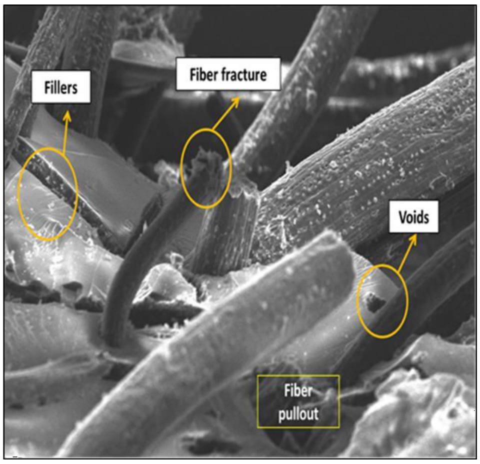
3.4.2 Micrograph analysis of flexural fractured specimen

Micro inference on fractured surfaces of the $CaCO_3$+ Groundnut shell coir-polyester composite specimen is shown in Figures 10 (a, b). It was revealed that fiber bending and fiber fracture were due to the flexural load in the 36 % fiber and 4% of filled added flexure sample. Matrix interfacial bonding is also in good condition so that achieves the maximum flexural value of 76.8 MPa. Fiber pull-out showed that some regions are due to the agglomeration of filler particles at high percentages. The high weight percentage of $CaCO_3$ and groundnut shell fillers causes the pull out and Voids in the laminate surfaces (KG Ashok *et al.*, 2020). It exhibits poor strength that has been observed in the fabricated composites.



(a)



(b)

Figure-10. Micro inference on fractured surfaces of the flexure sample.

4. CONCLUSIONS

Coir natural fiber reinforced polyester composite is fabricated using a compression molding machine with the addition of calcium carbonate and groundnut shell. The results are disclosed in this article, and these results are concluded in the following points.

- The non-woven coir fiber, calcium carbonate and groundnut filler materials added to reinforced polyester composites demonstrated better values of the tensile strength is 29.6 MPa.
- The maximum flexural strength was 76.8 MPa achieved by 38 % of fiber and filler content 4% in the $CaCO_3$ + Groundnut shell Coir-Polyester composites.
- The highest impact strength was enhanced by 34.8 kJ/m^2 in filler content 2% added in the composites.
- Fiber pullout, voids, interfacial bonding and fiber breakages were studied using the Scanning Electron Microscope.
- The results show that filler is one of the most important substances that can be added to composites to enhance their mechanical properties.
- Coir fiber-reinforced filler added composite materials are suitable for low load-bearing applications.

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