Effect of CaCo3 Particulate Filler on the Mechanical Properties of Surface Modified Coir Fibre/ Epoxy Composite

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Abstract. In this work, the effect of Calcium Carbonate (CaCo3) particulate filler on the mechanical properties of the coir fibre / Epoxy composites was studied. Calcium Carbonate was incorporated with Coir/Epoxy at different weight percentages such as 4%, 8%, 12%, 16% and 20%. Composite specimens were fabricated by incorporating surface-treated coir fibre at 15% fibre loading and powdered Calcium carbonate. Coir fibres were treated by 2% NaOH solution to improve the surface adhesion. Hand layup method was employed to fabricate the composite samples. As per ASTM standards mechanical properties were evaluated on specimens. The results indicated that the addition of CaCo3 on coir fibre/epoxy resin up to 16% filler loading could improve the tensile, flexural and impact strength. The mechanical properties were reduced by adding more than 16% of CaCo3 filler to the composites. The test results indicated a marginal increase in mechanical strengths and a relatively significant improvement in the mechanical moduli. SEM images of the tensile test samples were taken to study the surface morphology.

1. Introduction

Natural fibre reinforced polymer composites are widely studied under their inherent properties such as low density to high strength ratio, ease of availability, low cost and most importantly natural fibre is environmental friendly. Favourable properties of coir and other natural fibres are widely considered in engineering and technology for producing a different part as the body of an automobile and in many other fields. Natural fibres, unlike synthetic fibres are gaining popularity as they are grown naturally and can advantageously replace the glass or other synthetic fibre[1-4]. The Natural fibre composite materials play a good role in the materials world due to its properties such as biodegradability, lower thermal expansion coefficient, strength to weight ratio, easy availability, corrosion resistance and low cost than other conventional materials. Environmental changes majorly affect the cross-sectional area and shape of the natural fibre along with the length direction. Those changes in fibre materials reducing the ultimate load-carrying capacity of composites in engineering applications. In natural fibre composites, coir fibre plays an important role due to low cost, easy separation from the husk, low density, widely available in India and eco-friendly. Fillers are generally used to improve the mechanical behaviour of the composite [5-8]. Hongwei et al. [9] evaluated the compressive properties of nano-CaCo3/epoxy/carbon fibres and the effect of treated and untreated nano-CaCo3 on composites in the weight fraction 2wt%, 4wt%, 6wt% and 8wt%. Finally, it was reported that 4wt% of the nano CaCo3 increased compressive strength and modulus. Narendar et al. [10] fabricated hybrid composites using coir pith/nylon fabric/epoxy and highlighted that the chemically treated pith is reinforced with nylon/ epoxy composites is increased in their mechanical properties due to alkali treatment of coir pith.
and it improves the bonding between the coir fibre/nylon/epoxy resin. Geethamma et al.[11] analyzed the effect of coir fibre is treated with sodium hydroxide and sodium carbonate (NaOH and Na2CO3) of 5% solutions for 48 hours. They found that the properties of coir fibre can be improved by chemical treatment. Fanica Mustata et al. [12] evaluated the thermal behavior of composite materials prepared by some organic/inorganic materials with epoxy resin and calcium carbonate and found that the thermal stability can be increased with CaCO3. Qinghong Fang et al.[13] investigated the dynamic properties of nano-size calcium carbonate (NCC) added in natural rubber in the vulcanization process. The dynamic mechanical analysis (DMA) shows that the mechanical and morphologies analyses, Mullins effect, Payne effect and damping factor can be improved by adding CaCO3. Huang Gu [14] estimated tensile characteristics of the coir fibre and related composites after NaOH treatment in various concentrations of 2%, 4%, 6%, 8%, 10% separately. These research shows that the tensile strength of the coir fibre is improved in 2% of NaOH solutions. Hongwei et al.[15] studied the thermal and mechanical properties of nano-calcium carbonate/epoxy/carbon fibre composites. The compressive strength, flexural strength, and impact strength were increases due to the epoxy resin added on it. The research studies show that thermal stability and mechanical properties were increased and NCC minimized the defect between the fillers and polymer interface. The interlocking of these composites is determined by using SEM. Geethama et al. [16] analysed the dynamic mechanical behavior (DMB) of short coir fibre reinforced natural rubber composites. This study shows that DMB is in maximum in tanδ and E’’. The frequency increases the values of tanδ and E’’ decreased. Lakshmanan et al. [17] investigated the flexural strength of the coir-vinyl ester composites on calcium (eggshell) and reported that it improves the mechanical properties of the coir fibre composite. The flexural strength was reported as 28 MPa. Similarly Rajamuneeeswaran et al.[18] compared the mechanical properties of coir fibre reinforced polymer composites and reported that the coir/CaCO3/epoxy composites results better mechanical characteristics.

In this paper flexural, tensile and impact strength of the surface-modified coir/epoxy composite were estimated by incorporating the CaCO3 filler particles at different filler loadings.

2. Experimental

2.1. Materials

In this proposed work, natural composites epoxy resin was taken as the matrix material. Epoxy resin of grade LY556 and hardener HY951 was procured from Sakthi Fibres, Chennai. Processed coir fibre was procured from the local vendor from Chennai, the fibre was dried under the sun to remove any residual moisture present in the fibre. Calcium Carbonate was used as the filler material in this work.

2.2. Methods

Different weight percentage of coir fibre was measured after that it was chemically treated with 2% of Sodium Hydroxide (NaOH) solution for 48 hours then cleaned in water and allowed to get dry in atmospheric air condition to remove the unwanted contents from fibres. Weight percentage between fibre and epoxy (matrix material) and 10:1 ratio of the matrix material, hardener were maintained to prepare all the specimens. Various weight percentages (4, 8, 12, 16 and 20%) of CaCO3 were thoroughly mixed with the epoxy resin by mechanical stirring. Treated coir fibres are placed between two matched wooden moulds for the size of 300 x 300 mm. CaCO3 reinforced epoxy poured over the fibres and the mould was given a light compression to remove the excessive resin. After curing the samples were cut by water jet cutting as per the ASTM dimensions. Arrangement of fibre in Laminates and ASTM standards are given below in table 1. The weight fraction of Coir fibre in all the specimens was kept at 15%. ASTM D638 standard was followed to conduct tensile test at a crosshead speed of 5mm/min. The flexural test was conducted as per ASTM D790 and the impact test was conducted as per ASTM D 256 standards. Five specimens were used in each case and the average test value was tabulated. SEM images were taken to analyse the surface morphology of the tensile fractured specimens.
### Table 1. Arrangement of Fibre in Laminates

| Specimen ID | Filler loading (%)                     |
|-------------|----------------------------------------|
| CE4         | Coir fibre/epoxy with 4% of CaCo3      |
| CE8         | Coir fibre/epoxy with 8% of CaCo3      |
| CE12        | Coir fibre/epoxy with 12% of CaCo3     |
| CE16        | Coir fibre/epoxy with 16% of CaCo3     |
| CE20        | Coir fibre/epoxy with 20% of CaCo3     |

### 3. Results and Discussion

The Mechanical characteristics like Tensile Strength, Flexural Strength and Impact strength for different specimens were determined. The average value of the results obtained from the various tests was tabulated.

#### 3.1. Tensile Test

Tensile Test was conducted on a computer-controlled Universal Testing Machine (UTM) model F-100 with a maximum load capacity of 100 KN and the stress-strain plot was used to compute the tensile strength and tensile modulus of the samples. Figure 1 shows the impact of filler loading on the tensile properties of the composite samples. It was observed from the test results that the value of tensile strength slightly improved due to the addition of the particulate filler. The maximum tensile properties were obtained for the filler loading of 16%, further incorporation of the filler in the matrix resulted in a reduction in the tensile properties. The maximum value of tensile strength was obtained at 28.9 MPa. Since the fibers are in general carry the load and the stress is transferred from the matrix, the addition of filler had an insignificant change in the tensile properties. But it can also be noted that tensile modulus was significantly improved.

![Figure 1. Tensile strength of Epoxy composite for different CaCo3 filler loading](image)

#### 3.2. Flexural Test

The flexural test was performed by a 3-point bending method. The specimen was prepared according to ASTM D 790 where specimen size is 120mm length, 15mm width and 3mm thickness. The
properties such as flexural load and flexural strength were determined and the results were presented in figure 2.

![Figure 2. Flexural strength of Epoxy composite for different CaCO₃ filler loading](image)

The flexural strength also showed a similar trend as that of the tensile strength. The maximum flexural strength was observed for the specimen CE16 which consists of 16% CaCO₃ filler loading. The maximum flexural strength was obtained as 29.8 MPa and flexural modulus was obtained as 2215MPa. The test results showed that the particulate fillers can be used to increase the modulus values of the composites. The fibres can take the load directly from the matrix hence they play a vital role in composite strength, whereas the particulate fillers generally occupy the voids and they increase the matrix surface adhesion by improving the surface area of interaction. Particulates generally assist in transferring the load from the matrix and thereby increase the modulus values.

3.3. Impact Test

Impact test was performed on Charpy impact testing machine. Figure 3 shows the results of Charpy impact test for different percentages of CaCO₃ and it was observed that the peak value of impact strength was observed for the specimen CE12. While the addition of particulate filler slightly reduced the impact strength at 16% filler loading, the impact strength was further significantly reduced at 20% filler loading. The addition of the particulate filler had improved the impact strength by 4.25%. It is also observed from the figure that the impact strength values of specimens CE12 and CE16 were closer, indicating that the filler had an insignificant role in increasing the impact strength value of the specimens.
3.4. SEM Analysis

Tensile fractured surface was used to analyze the surface morphology between the fibre and matrix. The fibre pulls out and broken matrix was observed in figure 4 and figure 5. The particulate fillers were seen sparsely in the SEM images. This may be due to the significant size difference between the fibre and filler material. But the SEM images showed that the significant stress transfer is due to the presence of the fibres, rather than the particulate fillers. Figure 4 shows the surface morphology of the specimen CE16, the matrix crack due to the applied load was observed from this image. This indicates better matrix and fibre adhesion. Figure 5 shows fibre pull out due to the applied load. This indicates poor surface interaction between the reinforcement and the matrix.

4. Conclusion

In this study, composite specimens were prepared by using coir fibre and epoxy resin which was reinforced with CaCo$_3$ at different weight percentages 4%, 8%, 12%, 16% and 20%. The mechanical behavior of specimens was studied by tensile, flexural and impact tests. The test results showed an
insignificant effect of the addition of particulate filler in the values of tensile strength and flexural strength. Whereas the tensile modulus and flexural modulus were increased by 14.3% and 21.4% respectively. This indicates that the particulate filler assisted in increasing the strain to failure of the composite material. The impact strength was increased by 4.25% due to the addition of CaCO₃. SEM analysis showed that the effective stress transfer happened through the reinforcing coir fibre. The study showed that CaCO₃ can be used to increase mechanical moduli values while reducing the polymer content.

5. References

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