Effect of cascara/testa natural fiber reinforced (epoxy based)
hybrid composites

S.Mohamed Abbas¹, R.Manikandan*², G.Suresh³, S.Suberiya Begum², and
S.Selvi⁴

¹Saveetha School of Engineering, Saveetha University, Chennai – 602 105, India.
²Aalim Muhammed Salegh College of Engineering, Chennai – 600 055, India
³Rajalakshmi Institute of Technology, Kuthambakkam, Chennai – 600 124, India.
⁴S.A.Engineering College, Chennai – 600 077, India.

E-mail :* mani_fastmech@yahoo.co.in

Abstract: In this investigation, cascara/testa has been chosen as the particulate reinforcement agent along with the E-Glass fiber support, upon the epoxy matrix material. To carry out the experimental analysis, the standard ratio of cascara, testa and combinations of both have been selected as the particulate reinforcement, as 10% weight ratio of each respectively. Moreover to completely exploit mechanical behaviourism of the fabricated composite, physical analysis like tensile, flexural, impact and water absorption tests have been conducted as per the ASTM standards. In the pretext of the analysis, the strain rate of the tensile and flexural analysis has shown the increase of 3.5% and 2.75% respectively. In the same way, the impact analysis has also shown the hike in the absorption value as 1.25%, 1.12%. Furthermore the obtained results have shown that, the addition of cascara/testa have considerably increases the strain value and impact resistance of the fabricated specimens in sizeable manner by compromising the water uptake behaviour. Out of all standard tests, the hybrid composites (combination of cascara and testa) have shown the good conformity with all set of remaining specimens.

Keywords: cascara, testa, E-Glass, Epoxy, physical analysis, ASTM standards.

1. INTRODUCTION

The most promising and perspicacious material available in this century was identified to be composites. Currently, polymer composites with synthetic or natural material fibres are becoming highly prevalent as the demand for high strength to lightweight materials for unique applications is rising in the industry. In addition to the high strength to weight ratio, the composite fiber-reinforced polymer also shows outstanding properties such as durability, rigidity, damping resistance, flexural resistance, impact, corrosion, impact, wear and burn resistance [1-3]. These wide ranges of distinct requirements have made an advantage on composite materials to explore applications in mechanical, architectural, automotive, biomedical, marine, and various erstwhile manufacturing industries. Composite material recital depends greatly on its constituent elements and production methods, besides composite material performance depends primarily on its constituent elements and production techniques, so it is essential to learn the functional features of different fibres accessible worldwide as well as their classifications based on the manufacturing techniques which is used to produce the complex materials in order to determine the optimised characteristics of the material for the needed application [4-6].

A summary of broad series of fibres, their properties, classification and different fibre composite
production processes is provided for the exploration of optimised fibre reinforced composite materials for substantial uses. Their exceptional performance has pointed out the fiber-reinforced composite materials a viable choice to introverted metals or alloys in numerous application fields. The fiber reinforced plastic (FRP) materials are the conglomeration of more elements, in that, one of the element is considered as the matrix phase and the other may be present in a particle or fiber form [7-9]. Scientific studies from the previous two centuries have addressed that, composites are strongly believed as an alternative to many traditional materials, since it shows the marked improvement in the mechanical, structural properties of fibre/particulate reinforced composite (FRC) materials. Even though, the composite materials have achieved and proved mostly in the performance of the products, but there is presently, a considerable apprehension about the gathering of plastic waste has become as the alarm to eco system and environment. This challenge has forced investigators to produce environmentally responsible materials which in turn associated itself with the cleaner production processes [10-12].

To manage with the thousands of tonnes of plastic waste produced in an year, various composite materials salvage processes have also been created. Pulverization involves mechanical processing, where recyclates of reduced size are used as additive material for sheet moulding substances. Composite waste is degraded by pyrolysis during thermal recycling and burning the composite materials with very soaring calorific value, an massive amount of heat energy is generated. More successful processes including processes like chemical recycling (solvolysis) and high-voltage fragmentation (HVF) are also in operation at present. The incorporation of natural fillers like natural fibres, nanocrystals of cellulose and Nano fibrillated cellulose has significantly enhanced material properties of the polymer matrix in order to manufacture eco-friendly composites by minimising the problem of residue accumulation. Natural fibres are commonly categorised as plant, animal-based and mineral-based fibres. Recent studies have led to the formation of hybrid composites by mixing commonly available natural and synthetic fibres [13-15].

Hybrid composites are classified as composite structures, which consists of more than one fibre form. In specific applications, several researchers have achieved success by designing engineered composite materials for proficient use by varying fibre content, orientation, scale, or fabrication processes. Natural fibres (NFs) are a renewable material available in nature that is very easy to obtain, which also exhibits some exceptional material properties including such biodegradability, low cost per unit volume, high strength, precise rigidity are exposed. Natural fibres have common features with distinct compositions, depending on the type. Coffee is made from the bean produced from the coffee plant also it’s considered as one of the popular beverage, mostly consumed by human being by large across the world. While producing coffee only the coffee bean alone is been used, where as other parts of the bean like pulp, skin is kept removed and it is widely considered as the organic waste. Furthermore, the produced organic waste needs the proper disposal and needs the compost technology to properly convert this as the useful product [16-18].

Moreover recycling of these organic wastes needs sophisticated state of art technology to exclusively use this waste as the useful fertilizer. Similarly, the testa of the agricultural product also now a day’s widely considered as the organic waste all around the world. The exact definition of the testa is that, skin which covers the peanut. In addition to that during the extracting of the peanut, the testa is removed by the commonly known processes called blanching process. Normally it looks like thin skin with brown coloured layer. To remove the testa from the peanut, abrasive rollers have been used in most of the industries; this technology is widely used and accepted one, in order to save the peanut actual size and damage during extraction processes. Additionally, testa as well, would be easily extracted and collected in the common dumping system, follows that, it can also be very easily made into powdered form up to various mesh sizes [19-21].

In this study, the organic wastes like cascara and testa have been chosen as the particulate matter in the view to fabricate the composite laminate. Similarly the commonly available epoxy resin has been chosen as the matrix material. In order to exactly validate the individual particulate composite, the testa
with 10% of weight ratio has been loaded with the epoxy in the view to fabricate testa reinforced epoxy composite. As such as, the cascara with 10% also has been utilized to fabricate the composite laminate. Finally, to complete the validation of the testa and cascara loading into the epoxy, in the view of, to fabricate the hybrid composite, the 5% (wt.ratio) of cascara along with the 5% (wt.ratio) of testa have been thoroughly mixed with epoxy matrix in order to fabricate the testa and cascara hybrid composite laminate. Meanwhile the E-Glass fiber has been chosen as the base fiber to get the complete structural rigidity on the fabricated composite laminate. In order to complete evaluate the mechanical behaviour of fabricated laminate, tests like tensile, flexural, impact, and moisture analysis are carried out and compared with each other [22-24].

2. MATERIALS AND METHODS

2.1 Materials
Testa and cascara powders with standard specification were received from the saraswathi traders and exporters, Coimbatore. Both the powders were used as such received from the manufactured place as shown in the figure 1. In the same way, epoxy resin and E-Glass fiber with 350 GSM was procured from sakthi fibers, Chennai. All the samples were used for fabrication purpose without any chemical or purification processes [25].

![Figure 1. (a) Powder form of cascara (b) Powder form of testa](image)

2.2 Fabrication Methodology
To fabricate the testa and cascara loaded hybrid E-Glass fiber reinforced epoxy laminate the following sequential steps were followed. The pre cut E-Glass fiber with aerial density of 350 GSM was sized first, with the dimension of 300 mm x 300 mm. The measured testa/cascara with 5% weight ratio was loaded into the epoxy matrix consecutively, similarly the combination of the both like 5% testa and 5% cascara was loaded into the epoxy and measured with the exact weight accuracy and kept in the separate beaker as combinations mentioned in the table 1.

| Specimen | E-Glass fiber (wt.%) | Epoxy (wt.%) | Particulates (wt.%) |
|----------|---------------------|-------------|-------------------|
| EPG      | 60%                 | 40%         | 0%                |
| EPC      | 60%                 | 40%         | 10% Cascara       |
| EPT      | 60%                 | 40%         | 10% Testa         |
| EPCT     | 60%                 | 40%         | 5% Cascara + 5% Testa |

To do the fabrication process, initially the flatten surface was chosen to do the hand lay up technique processes; the entire surface was coated with polyvinyl glycol as to act as the releasing agent. After this, the precut fiber was wetted with the epoxy (loaded/unloaded), during the entire processes the metallic roller was used to ooze out the excess amount of resin from the laminate, in order to avoid the void presence inside the laminate. The entire fabrication sequence was followed as per the combinations mentioned in the table 1. Once the entire fabrication was got over, the laminates were allowed to cure into open air for the period of 24 hours. However to get the complete polymerization, the entire laminates were kept in the hot air oven for the period of 2 hours by maintaining the temperature of 80°. Besides that, the side edges were completely cut off from the unwanted projections [26].
2.3 Experimental methodology
The laminates/slabs were cut according to the ASTM standards as mentioned in the table 2.

| S.No. | ASTM Standards | Size of the specimen (Length x breadth x thickness in “mm”) |
|-------|----------------|----------------------------------------------------------|
| 1.    | ASTM D 3039    | 250 x 25 x 3.2                                          |
| 2.    | ASTM D 790     | 127 x 12.7 x 3.2                                        |
| 3.    | ASTM D 256     | 63 x 12.8 x 3.2                                         |
| 5.    | ASTM D 570     | 25.4 × 76.2 × 3                                         |

To do the tensile test analysis, shaped test specimens were initially gripped into the Instron Universal Testing Machine (20 kN) with the cross head speed of 2 mm/min, until the specimens were completely fractured. Similarly, the flexural test specimens were kept over the flexural test set up and subjected with the transverse load, with the cross head speed of 2 mm/min. The absorbed values were noted with help of the digital meter provided in the UTM. Similarly, as such readings were noted in the tensile and flexural, impact tests were also done on the fabricated specimens with help of the izod impact testing kit. Along with the above tests, specimens were also subjected with the moisture absorption test, to completely know about the water uptake behaviour of the natural particulate reinforced epoxy specimens [27-28].

3. RESULTS AND DISCUSSION

3.1 Effect of cascara/testa particulate reinforcement on tensile behaviour of laminate.
The figure 2 shows the tensile test analysis of cascara/testa natural particulate reinforced epoxy based laminate.

![Tensile test analysis of cascara/testa particulate reinforced epoxy laminate](image)

During the tensile test analysis it is observed that, the pure or neat (0%) E-Glass fiber reinforced epoxy laminate has showed the tensile strength value as 452 MPa, this value is quite higher than the value of remaining all set of proportionate; also it stood as top, as compared with all set of natural fiber particulate composites. Similarly the strain rate of the respective specimen is nearly 1.4. Whereas the 10% cascara loaded epoxy compound has shown the tensile stress value has nearly 415 MPa along with the E-Glass fiber reinforcement, and their consecutive strain rate is observed as 0.9. From the results it is observed that, the neat epoxy and E-Glass fiber reinforcement has shown the higher value as compared with the all set of natural particulate reinforcement. In the pretext of the above experiment, it is predominately proved that, the strain rate of the specimens significantly improved upon loading of
the natural fiber particulate along with the epoxy matrix compound. Also from the remaining set of testa reinforcement, the value is observed as 420 MPa, the obtained value is quite higher than the cascara particulate reinforcement and their corresponding strain rate is nearly 0.85. It is quite interesting to note that, the strain rate of the cascara/testa has drastically come down with appropriate loading of particulate composite. The reason behind that the entire strain rate decrease is that, the loading of particulates, it seems that particulates are evenly distribute itself on the entire epoxy matrix and takes the load of the composite, that is the reason why, the strength value decreases and the corresponding strain rate increases to the appropriate level. Furthermore the same set of value also have been noticed in the 5% cascara and 5% testa hybrid composite, though the strength value is not compromising as compared with the remaining set of individual particulate loading. substantial strain rate improves up to the level of 0.8. It is proved that, even though the strength decreases due to the addition of natural particulates, negotiable rate of strain rate improves to the massive level. Apart from that, the common failure fracture mechanism like fiber pullout and matrix cracking is seen all specimens irrespective of particulate loading [29-30].

3.2 Effect of cascara/testa particulate reinforcement on flexural strength behaviour of laminate.

The figure 3 shows the flexural strength analysis of cascara/testa particulate reinforced epoxy based composite laminate.

It is observed that, the flexural test analysis of the neat epoxy based (0%) composite has shown the stress value as 380 MPa and their corresponding strain rate is 1.8%. As such discussed in the tensile stress analysis, in flexural analysis as well, the results have shown the same set of trend value as such observed in the tensile strength analysis. The 10% cascara reinforced particulate composite specimen has shown the flexural strength value as 355 MPa as against the strain rate value of 1.1%. The obtained results revealed that, the particulates are evenly distributed into the epoxy matrix and thus the way it induces the substantial hike in the strain rate as against the decreasing effect of flexural strength. Along the side of above results, the 10% testa reinforced specimens also have shown the flexural strength value of 360 MPa as against the strain rate value of 0.95%. whereas the hybrid combination of testa and cascara have shown the value of 363 MPa along with the strain rate of 0.97%. From the above experimental analysis, it shows that, increase in the value of natural particulate largely decreases the flexural strength value but proportionally increases the strain rate in sizeable manner [31-32].

Figure 3 flexural strength analysis of cascara/testa particulate reinforced epoxy laminate

3.3 Effect of cascara/testa particulate reinforcement on impact strength behaviour of laminate.

The figure 4 illustrates the impact behaviour of natural fiber reinforced epoxy based composite laminate.
Figure 4 flexural strength analysis of cascara/testa particulate reinforced epoxy laminate

It is observed that, the impact analysis have shown the different set of trend line as against the tensile, flexural test analysis. In tensile, flexural analysis, as much as addition of natural particulate into the epoxy matrix significantly reduces the laminate strength in considerable level. But, whereas in impact analysis, reverse trend is noticed. To prove the above statement, the neat epoxy and E-Glass fiber reinforcement has shown the impact strength value as 16 kJ/m$^2$, in the same way the cascara reinforced epoxy compound has shown the impact strength value as 18 kJ/m$^2$, the natural particulate reinforcement improves the impact strength value to phenomenal level, the obtained value has showed the evidence for that. Likewise, the testa particulate reinforced epoxy specimens also have shown the impact strength value as 17.5 kJ/m$^2$. Over and above, the hybrid composites (5% cascara + 5% testa) have shown very good impact absorption strength by giving the value as 19.5 kJ/m$^2$. It shows the natural particulate reinforced composite has good enough to absorb the excess amount of vibration and impact loads as against the neat epoxy based compounds [33-34].

3.4 Effect of cascara/testa particulate reinforcement on moisture absorption behaviour of laminate.

The figure 5 shows the moisture absorption behaviour of various natural fiber particulate loaded epoxy based composites.

The moisture absorption behaviour of the neat epoxy based composites has shown the water uptake value as 3.5%. Whereas the cascara reinforced epoxy laminate has shown the moisture absorption value as 4.1%, the obtained value is nearly 14.63% higher than the neat epoxy composite. From the results, it has shown that, the natural fiber reinforcement shown the predominant moisture sensitiveness which is been widely believed as the property called hydrophilicity. The hydrophobic natures of the fibers are seemingly increases the water uptake value to the appropriate level to the massive level. Similarly the testa reinforced composites also have shown the moisture absorption value as 4.78%, the obtained value is nearly 16.5% higher than the cascara particulate reinforced composites. In the pretext of the above, the hybrid (cascara + testa) reinforced hybrid composites have shown the massive level of water uptake as compared with the remaining set of other combinations. The prime reason behind that of water uptake was that, the hydrophobic nature of the natural fiber composites [35].
4. CONCLUSION

The cascara/testa reinforced epoxy composites were fabricated successfully and subjected with various mechanical analyses like tensile, flexural, impact and moisture absorption tests. The following observations were noted upon doing the standard tests, as per ASTM procedure.

1. The cascara/testa fiber was successfully used as the natural fiber reinforcement along with the E-Glass fiber, by choosing epoxy as the matrix material.
2. The tests like tensile, flexural shown the substantial level of strength values, where as the loading of the natural particulate significantly increases the strain rate to appropriate level.
3. In the contrary to the above results, the impact test results had shown the noteworthy level of improvement, upon loading the natural particulate into the epoxy composites. Nevertheless, the combinations of the cascara and testa had shown good sign in impact analysis procedure.

Similarly, moisture absorption tests also had shown the negative set of trend, depends upon the natural fiber reinforcement the water uptake value increases to apposite level.

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