Fabrication and Exploration of Mechanical Properties of Natural Composites with Epoxy Polymer Matrix by using Reinforcements of Egg shell powder, Coconut powder and Borassus flabellifer

B. MADHUSUDANA REDDY[1] S. P. AKBAR HUSSAIN[2] Dr. M. SREENIVASULU [3]

[1] Assistant professor, Dept. of Mechanical Engineering, NBKRIST, Vidyanagar, Nellore dist, , A.P, INDIA
[2] Assoc. Professor , Dept. of Mechanical Engineering, NBKRIST, Vidyanagar, Nellore dist, , A.P, INDIA
[3] Professor, Dept. of Mechanical Engineering, NBKRIST, Vidyanagar, Nellore dist, , A.P, INDIA

Abstract : **Development of the natural fiber reinforced polymer composite is rapidly growing both in terms of their industrial applications and fundamental research because of its high strength to weight ratio especially in structural applications, fabrication can be made at economy cost and higher utilization of available resources. Composite materials reduce the weight and improve the mechanical properties.**
Natural composites have been proven alternative to synthetic materials. The present paper is focusing on fabrication and exploration of the new composite material by hand lay-up method. In this work, polymer matrix (Epoxy resin(LY 556) and Hardener(HY 951) is used as the thermo set matrix material and reinforced constituents used in this matrix are as coconut shell powder, egg shell powder, and Palmyra tree fiber (Borassus flabellifer) in different weight proportions. Such a composite is usually called as PEC composite. Test specimens were prepared in accordance to the ASTM standards and tested for various mechanical properties. The experimental values obtained from tests are more useful in the development of Natural composites for different applications.

Keywords: **Borassus flabellifer, Egg shell powder, Coconut shell powder, PEC, Epoxy resin (LY 556) and Hardener (HY 951), Hand lay-up method.**

I. INTRODUCTION

Composites are derived from a family of materials whose stiffness, strength, density, thermal properties and electrical properties are tailored on the basis of requirement. Nature provided abundant materials naturally, which are eco-friendly and renewable. Several researchers have put their efforts on developing the natural fiber reinforced materials. Tailored natural composites are light in weight with good strengthtc. Whereas problems associated with the fiber extraction and curing process are to be handled properly. Care should be taken on handling or maintaining the appropriate moisture content at the time of incorporating them into the polymer matrix.

Nadendla Srinivasababu *et al.*,[1], fabricated the composite material by hand layup method with polyester resin by reinforcing with the natural fiber of long Petiole of Palmyra tree. And they tested for mechanical properties and stated that highest tensile strength was increased from 56.69 MPa to 1052.8 MPa and also reported that the improvement in the flexural strength and few other properties have increased from 3.16 % to 34.76 %. Increase in impact strength is reported to be by 97.07% with the composites in particular reinforced with Palmyra palm petiole fiber than the plain specimen.

Jefri Bale *et al.*, [2], have studied the tensile strength of various samples which are made by the unsaturated polyester as the matrix material and lontar (palm) fiber as reinforcement by using hand layup method. The tensile test was performed on all test samples until the final fracture. Three specimens for each type of hole configuration were tested and it was concluded that the specific area of four-hole specimens (diamond array and square pattern) experiences resulted smaller strain propagation when compared to the specimens containing one hole or two-hole pattern. Finally, they hoped that, due to the above reason, objects reinforced by the lontar fiber are suitable for mechanical joints.

M Thiruchitrambalam *et al.*,[3], made investigations on the mechanical properties such as tensile strength, flexural strength and impact strength on the composites which were made by the Palmyra palm leaf stalk fibers and unsaturated polyester matrix. These researchers have treated the reinforcing fibers with Mercerization, benzoylation, and permanganate. Also observed that Mercerized and benzoyl-treated fiber composites had an improvement of the order 60% in tensile strength, the tensile modulus increased by about 37% and 60%, respectively. They have reported that the flexural strength have increased by 70% and flexural modulus increased by 110%. The impact strength for the Mercerized and permanganate-treated fiber composite improved by 55% and 42%. They reported that the treated fibers absorb the less water when compared with the untreated composites.
Dhandapani Saravanan *et al.*, [4], have prepared the composites by using the Palmyra fruit extract fibers and studied the various properties and reported that this would be the good potential fiber for reinforcing the composites.

William Jordan *et al.,* [5] have made extensive studies on the interfacial bonding between the Banana fiber and LDPE matrix material. They treated the fiber with the two different chemicals like peroxide and permanganate treatment. Finally they concluded that the peroxide treatment fibers gave the better results than the later one.

Muhammad Hanafi Md Sah *et al.,* [6] have extended their research on fabricating the composite using PVC matrix was reinforced with coconut shell powder. After which it was tested to know the improvement. The experimental results indicated that tensile strength, impact strength and flexural strengths were noticeably improved by an extent of about 42%, 25% and 23% respectively over the pure system.

R. Udhayasankar *et al.,* [7] have performed an extensive review on the composites which was prepared by using the naturally available materials. In their work, it has been concentrated and evaluated the development of coconut shell fibers reinforced polymer composites with its manufacturing processes, methodology and also to find not only the mechanical properties but also the thermal analysis was carried out and they have taken into account some of the applications.

Pavan Hiremath *et al.,* [8] have made thorugh investigations on the mechanical properties of composite that are made with the polyester resin matrix and which were reinforced with the egg shell powder and glass fiber. Finally they have concluded that the bending load taken by both 5% and 10% filler composite is almost the same but the deflection of 10% filler composite is less than both the 0% and 5% filler composite. Also reported that more than 5% of usage of filler material in the composite caused reduced hardness.

S.B. Hassan *et al.,* [9] have made an attempt to fabricate the composite by using the eggshell reinforcement particulates and polyester matrix. They used 10% to 50% of weight ratios of reinforcement for their samples for their study. They have stated that the mechanical properties and density were carried out by standard methods. From the results it is understood that the density and hardness values of the polyester/eggshell particulate composite increased steadily with increasing eggshell addition.

Anjali, Rajia *et al.,* [10] have made an attempt to prepare the composite material samples with Aluminum- Silicon alloy matrix and eggshell powder as reinforcement. They noticed a considerable improvement in the properties such as tensile strength, modulus of elasticity, hardness, toughness, impact and compressive strengths.

Shashir S.K *et al.,* [11] have recognized the emerging of fiber reinforced composites and studied on the improvement on the properties of the composite. Their main focus was on the mechanical behavior of eggshell reinforced epoxy composites. Composites samples with 0, 10 and 20% weight fraction of eggshell. In their study they have followed hand layup method. Finally they observed that 20% of filler material produced better results and water absorption also increased with an increas in the filler material.

J.O. Agunsoye *et al.,* [12] have worked on recycling the used and disposable aluminum cans as a metal matrix and they reinforced this material with the 150 µm eggshell powder and tested for their mechanical properties. They concluded that the Aluminum cans waste of different beverage products can be recycled and can used as an essential matrix material. They have reported that this matrix material reinforced with naturally available material would conveniently used in the preparation of useful products which in turn leads to economical and environment-friendly.

B. Madhusudhana Reddy *et al.,* [13] have made extensive studies on the mechanical properties of various samples of composites made by the coconut coir, eggshell powder reinforcements and with the resin-based matrix material. They concluded that the tensile strength is mainly depends on the coconut coir fiber whereas, compressive strength depends on eggshell powder and impact strength depends moderately on both the reinforcements.

From the review it was understood that many researchers have made extensive study on natural fiber reinforcements and reported that there are various benefits from naturally reinforced composites. It was proved that usage of naturally available and disposable materials is a better approach to get an engineered material with desired properties. In the present work investigations were carried out on the fabrication and evaluation of a composite using epoxy matrix and eggshell powder, coconut powder and Borassus flabellifer are used as reinforcements.

II. Materials and Methods

The composite materials are prepared by different matrix materials such as MMCs, PMCs and CMCs which are reinforced by the different materials. These composites fabricated by the different methods like Manual Lay-Up method, Automated Lay-Up method, Prepreg method, Filament method, Spray-Up method and Pultrusion etc., Among those Manual Lay-Up or Hand Lay-Up method is easy and best method and hence this method is followed in the present work.

2.1 Hand Lay-Up method

Hand Lay-up method is the common method and least cost method which requires minimum equipment on its execution.

2.2 Materials

In the present work Epoxy resin (LY 556) and Hardener(HY 951) are used as a matrix material and Egg shell powder, Coconut shell powder, Borassus flabellifer are used as reinforcements.

2.3 Preparation of Egg shell powder

Egg shells were collected from the locally available places. Later they were dried for 5 days in hot sun and cleaned the inner portions and dipped into sodium carbonate solution for further cleaning. Egg shells were taken out from the solution are dried for another two more days. Properly dried egg shells are only used for making powder. Grinders/ Millers are used to grind the dried egg shells in the preparation of powder. Appropriate care was taken to get fine powder as it is required for proper mixing with other material.

2.4 Preparation of Coconut shell powder

Coconut shells were dried under sun shine for few days and the powdered with the help of millers and grinders to get fine powder to the possible extent.

Proper care was taken to ensure that both the powders were made into more or less same size of particles to get homogeneity. In order to ensure this by using a sleeve having grain size of 75 microns and both the powders are taken and sleeved.

2.5 Fiber Extraction and Cleaning

Fibers are extracted from the Palmyra tree stem. Care was taken in removing the soft tissue from the fibers. Thus extracted tissues were soaked in the NaOH solution tub for about 24 hours. This fiber was washed with lot of water and dried in the sun shine till the entire moisture was removed.

III. Manufacturing of composite Samples

- Properly cleaned Palmyra fibber is cut in to small pieces.
- The three materials eggshell powder, coconut powder and Borassus flabellifer are taken as per the predetermined proportions.
- They are thoroughly mixed without which it is not possible to get improvement in the properties.
- The epoxy resin and hardener are taken in the ratio of 1:10.
- This mixture was stirred thoroughly for proper mixing.
- Density of the hardener noticed to be higher than that of epoxy, this eases the mixing of hardener with the epoxy.
- During stirring the three material mixtures (eggshell powder, coconut powder and Borassus flabellifer) which was prepared earlier was added slowly to this to get PEC.
- Two tiles are taken and the wax and engine oil applied are applied on them to avoid sticking the material to the tiles.
- Oil applied on the tile also ensures the attainment of good surface finish of the product.
- Then the mould cavity was placed on the tile.
- Thoroughly mixed material was then used to fill the mould cavity.
- Proper care was taken while filling the cavity.

Fig. 1. Fabricated material

- The material is carefully removed from the cavity.
- The resultant and obtained “PEC” natural composite material was allowed to dry.
- The material is made in to pieces as per the ASTM standard dimensions for various mechanical testing.

IV. Testing of Mechanical properties

PEC is a composite material having the combination of the Palmyra fiber, coconut and egg shell powder. Table 1 gives the details of the mixture proportions that are used to prepare the samples and are represented as R_1, R_2, R_3 and R_4.

It was ensured that the sum of ratio of % of weights of all three reinforcements was equal to 40%. Among these % of weight of coconut powder was limited to 20 % and remaining 60% was ensured to be polymer matrix material.

Table: 1 Reinforcement proportions

Material	R_1%	R_2%	R_3%	R_4%
Palmyra	3	4	5	6
Coconut shell	20	20	20	20
Egg shell	17	16	15	14

4.1 Flexural test

The bending load at break for a composite with different proportions of materials are presented in table 2. The bending strength was calculated using the equation.

Moment (M) = load (N)*length (L/2)

Moment of inertia (I) = $(bd^3/12)$

Y = (d/2)

Section modules (Z) = (I/Y) = $(bd^2/6)$

(M/I) = (F/Y)

Where b=breadth of the specimen
d=height of the specimen
L= length of the specimen

Bending strength, F = (M/Z)

Fig. 3. Specimen under Flexural test

Table: 2 Flexural Strength

Sample No.	Composition	Flexural Strength N/mm^2
1	R_1%	326.90
2	R_2%	344.86
3	R_3%	350.90
4	R_4%	361.30

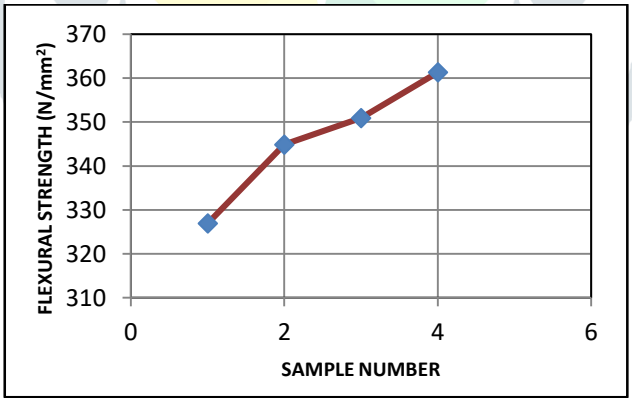

Fig: 4. Flexural Strength Vs Sample Numbers

4.2 Compression Strength

The compression load at break for a composite with different proportions of materials are presented in table 3. The compression strength was calculated using the following equation.

$$\text{Compression strength} = \frac{Load\ at\ break\ (N)}{Area\ of\ the\ specimen\ (mm^2)}$$

Fig. 5. Specimen under Compression test

Table 3: Compression Strength

Sample No.	Composition	Compression Strength N/mm^2
1	R_1%	170
2	R_2%	180
3	R_3%	220
4	R_4%	210

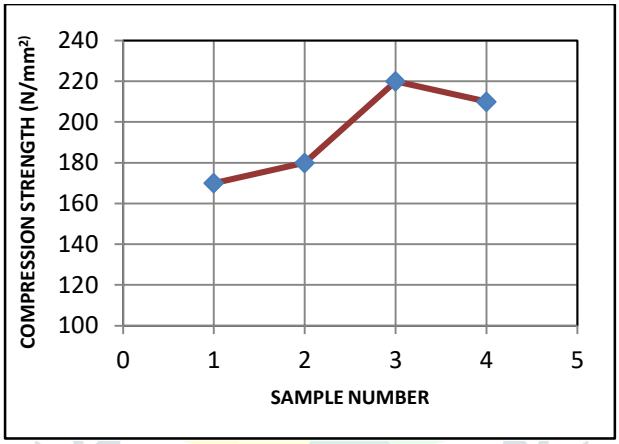

Fig: 6. Compression Strength Vs Sample Numbers

4.3 Impact Strength

The impact strength (Izod test) of a composite material with different proportions of materials are presented in the Table 4. The impact strength was calculated using the equation.

Impact strength = $(E_2-E_1)/a$

Where, a=area of cross section

E_2=energy absorbed for breaking the specimen

E_1= energy absorbed without specimen i.e., 0 (zero) joules.

Fig. 7. Izod Impact machine

Fig: 8. Specimens for Impact Strength

Table:4. Impact Strength

Sample No.	Composition	Impact Strength J/mm^2
1	R_1%	0.025
2	R_2%	0.0275
3	R_3%	0.0325
4	R_4%	0.0375

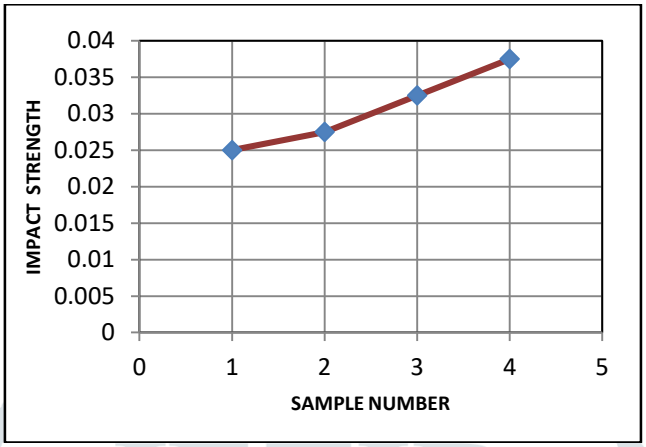

Fig: 9. Impact Strength Vs Sample Numbers

The impact strength (Izod test) of a composite material with different proportions of materials are presented in the table 4. The impact strength was calculated using the equation

Impact strength = $(E_2-E_1)/a$

Where, a=area of cross section

E_2=energy absorbed for breaking the specimen

E_1= energy absorbed without specimen

i.e., 0 (zero) joules.

4.4 Hardness number

The hardness of specimens can be determined by various testing instruments like Rockwell, Brinell and Vickers testers.

In the present work, Brinell hardness tester with 1/12" indenter was used for testing and 60 kgf. force was applied for determining the hardness.

The Hardness numbers with sample wise are tabulated in the table 5.

$$\text{Brinell Hardness Number HBN} = \frac{Test\ Force\ (F)}{Surface\ Area\ of\ Indentation(A)}$$

$$\text{HBN} = \frac{2F}{\pi D\left(D-\sqrt{D^2-d^2}\right)}$$

Table 5.Hardness number

Sample No.	Composition	Hardness number
1	R_1%	25.3
2	R_2%	30
3	R_3%	34.3
4	R_4%	41

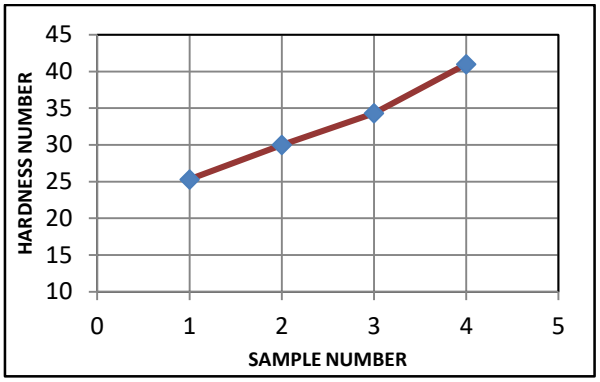

Fig. 10. Hardness number Vs Sample Numbers

V. Conclusions and Discussions

A detailed study was carried out on the mechanical behavior of PEC composite material with different proportion of these three reinforced materials with the constant polymer matrix composition. The study led to the following conclusions:

- Bio-composites lead to the reduction in weight and costs and are noticed to be environmental friendly.
- Increased values of various properties contribute for their usage in various applications.
- The flexural strength of composite has increased linearly in all the compositions. But, by careful observations it can be noticed that the increased proportions of Palmyra and reduced proportions of egg shell powder have raised the flexural strength.
- Reduced proportions of egg shell powder has played an important role in the improvement of compressive strength up to certain extent.
- The flexural strength, hardness number and impact strength of the composite have improved for the materials from R_1 to R_4 .
- From the graphs it can be concluded that the materials R_3 & R_4 are found to be have better properties when compared to the materials R_1 & R_2.
- Whereas, R_4 composition is found to have altogether higher properties among all the four compositions excluding the Compression strength.

REFERENCES

1. N. Srinivasababu, J. S. Kumar, and K. V. Reddy, "Manufacturing and Characterization of Long Palmyra Palm/Borassus Flabellifer Petiole Fibre Reinforced Polyester Composites," *Procedia Technology*, vol. 14, pp. 252–259, 2014.
2. Jefri Bale, Kristomus Boimau, and Marselinus Nenobesi, "Natural Composite Reinforced by Lontar (*Borassus flabellifer*) Fiber: An Experimental Study on Open-Hole Tensile Strength", Hindawi, International Journal of Biomaterials, Volume 2017, Article ID 7685047, 8 pages.
3. Thiruchitrambalam, M., Shanmugam, D., 2012. Influence of pre-treatments on the mechanical properties of palmyra palm leaf stalk fiber– polyester composites, Journal of Reinforced Plastics and Composites 31, p. 1400.
4. Dhandapani Saravanan , N. Pallavi , R. Balaji & R. Parthiban (2008) Investigations into structural aspects of Borassus flabellifer L (palmyrah palm) fruit fibres, The Journal of The Textile Institute, 99:2, 133-140.
5. William Jordan, Patrick Chester, Improving the Properties of Banana Fiber Reinforced Polymeric Composites by Treating the Fibers , 3rd International Conference on Natural Fibers: Advanced Materials for a Greener World, ICNF 2017, 21-23 June 2017, Braga, Portugal.
6. Muhammad Hanafi Md Sah, Alias Mohd Noo, Muhammad Rabiu Abbas, "Mechanical Properties of Coconut Shell Powder Reinforced PVC Composites in Automotive Applications", Faculty of Mechanical Engineering at Universiti Teknologi MARA (UiTM), Malaysia, Accepted for publication: 2017-04-13;
7. R. Udhayasankar and B. Karthikeyan, "A Review on Coconut Shell Reinforced Composites" , International Journal of ChemTech Research CODEN (USA): IJCRGG ISSN: 0974-4290, Vol.8, No.11 pp 624-637, 2015
8. Pavan Hirematha, Manjunath Shettar, Gowri Shankar M C, N S Mohan," Investigation on Effect of Egg Shell Powder on Mechanical Properties of GFRP Composites", ScienceDirect, Materials Today: Proceedings 5 (2018) 3014–3018, Elsevier.
9. S.B. Hassan , V.S. Aigbodion , S.N. Patrick, "Development of Polyester/Eggshell Particulate Composites", Vol. 34, No. 4 (2012) 217-225; Tribology in Industry; www.tribology.fink.rs.
10. Anjali, Razia Malik, Shivani Bhandari et al, " Fabrication and Mechanical Testing of Egg Shell Particles Reinforced Al-Si Composites", International Journal of Mathematical, Engineering and Management Sciences Vol. 2, No. 1, 53–62, 2017 ISSN: 2455-7749 .
11. Shashir S.K, Apsarraj A.D, Shashidhar A.L, Basavaroodh A.B, " Experimental investigation of mechanical properties of egg shell powder reinforced with epoxy" July 2017, Volume 4, Issue 07 JETIR (ISSN-2349-5162)
12. J.O. Agunsoye , S.A. Bello , I.S. Talabi , A.A. Yekinni , I.A. Raheem , A.D. Oderinde , T.E. Idegbekwu, " Recycled Aluminium Cans/Eggshell Composites: Evaluation of Mechanical and Wear Resistance Properties", Vol. 37, No. 1 (2015) 107-116, Tribology in Industry, www.tribology.fink.rs.
13. B. Ashok , S. Naresh , K. Obi Reddy , K. Madhukar 1, J. Cai , L. Zhang , A. Varada Rajulu; "Tensile and Thermal Properties of Poly(lactic acid)/Egg Shell Powder Composite Films", Arti *in* International Journal of Polymer Analysis and Characterization 19(3) · March 2014.

About The Authors

Mr. B. Madhusudhana Reddy, Assistant Professor, Department of Mechanical Engineering, N. B. K. R. Institute of Science and Technology, Vidyanagar, S. P. S. R Nellore District, Andhra Pradesh, India.
Qualifications: M.Tech., (Industrial Engineering) from S.V. University, Tirupathi.

Mr. S. P. Akbar Hussain, Associate Professor, Department of Mechanical Engineering, N. B. K. R. Institute of Science and Technology, Vidyanagar, S. P. S. R Nellore District, Andhra Pradesh, India.
Qualifications: M.S on Applied Materials and Manufacturing from King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Dr. M. Sreenivasulu, Professor, Department of Mechanical Engineering, N. B. K. R. Institute of Science and Technology, Vidyanagar, S. P. S. R Nellore District, Andhra Pradesh, India.
Qualifications: M.Tech., Ph.D.,