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Mechanical Properties of Duck Eggshell Powder Reinforced Epoxy Composites - A Study on Effect of Reinforcement

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ABSTRACT: The world produces roughly 7.2 million tons of eggshell waste each year, which is about 11% of the weight of an egg. The leading egg-producing countries are China, India, and the United States[7)]. However, eggshell waste can also contribute to environmental pollution if it's disposed of in landfills. In landfills, eggshell waste can produce odors and encourage microbial growth. However, eggshells can be used in many ways including production of composite materials. Duck eggshells are popularly stronger than chicken eggshells, with a more compact palisade layer and higher calcium content. Since eggshells are a source of calcium carbonate (CaCO3), they could be used as fillers in composite materials to improve the mechanical properties[1)]. Using eggshell waste as fillers can help to reduce waste and increase the strength and wear resistance of the final product. This work aimed, for the first time, to investigate mechanical properties of duck eggshell epoxy *composites.* Duck eggshell powder is used with epoxy resin to prepare the composite material. Different types of composites are prepared using different wt% duck eggshell powder with epoxy matrix material. The composites are manufactured by simple casting pouring process. Specimens cut and tested for physical and mechanical properties according to ASTM standards. The experimental results substantiate the potential use of duck eggshell powder as a reinforcement filler in polymeric composites, with 12 wt% being the optimal weight fraction for further applications.

KEYWORDS: Duck Eggshell, Epoxy, Mechanical properties

I. INTRODUCTION

A composite material is prepared by using two materials such as, reinforcement and matrix that have entirely different properties. Reinforcement material plays a key role in making composite material. A polymer composite is a material consisting of more than one phase in which reinforcing phase is integrated with a polymer. Composite material, the superior material is becoming a vital part of today's material industry due to the benefits such as light weight, corrosion resistance strong, stiff, and tough. They are extensively used as materials in the manufacture of automotive and aircraft structures, and space vehicle. The commonly designed composites utilize a polymer based material often called a resin solution. The generally used resin solution are epoxy, polypropylene, polyethylene, polyester, vinyl ester, phenolic, polyimide, polyether ether ketone (PEEK) and others. Polymer based composites are in demand due to their inexpensive and simple fabrication techniques. Powder-reinforced polymer composite is a newest material that are prepared by combining rigid reinforcement particles with a polymer matrix. The reinforcement particles can enhance the properties of the composite, such as its strength and toughness. Eggshells are a biodegradable material, and they could be utilized as reinforcement filler in bio-epoxy composites which could then be selected for variety of applications that involve a greater strength and lower cost. It also helps to address challenges faced by every waste disposal infrastructure. Commonly egg shells are considered to be waste byproduct in many food industries, restaurants, houses etc. and eggshell powder can be believed as a substitute to the standard plant-based materials. The attempt to use waste eggshells in polymer composite is an effort to decrease the negative effects of waste on environment. The powder obtained from eggshells as a source of calcium carbonate can be successfully used to alter the properties of polymer composite.

II. COMPOSITE MANUFACTURING

The composite is prepared by using ply wood mold. Later the required dimensional area is marked to manufacture the composite. The steps followed during the manufacture of composite plate is described below:

A. Eggshell Powder Preparation

Duck eggshell was obtained from Central Poultry Development Organization in the city of Hessaraghatta, Bangalore, Karnataka, India. Then, the duck eggshells were dried under solar dryer for 48 hours. Required amount of powder was taken and ground into powder (size: 100 µm). A sieve was used to obtain an average duck eggshell powder particles size of 100 µm. The powder was treated with a solution of Sodium Hypo chloride (NaOCl), to remove the dust particles.

B. Preparation of Test Samples

Epoxy resins are regularly used resins for most advanced composites because of their excellent adhesion, superior mechanical and electrical properties, and good stability at prominent temperatures. Epoxy LY-556 resin was used as matrix and hardener HY-951 for room temperature curing. A releasing agent, such as wax, is applied on the working surface of the mold for simple composite removal, before the fabrication activity begins. Three molds of various sizes were utilized for fabrication of the composite plates. The weighed resin and hardener in a 10:1 identical ratio, in addition with weighed eggshell powder (Based on the theoretical calculated weight of composite) was stirred manually until the homogeneous mixture was produced. Later the homogeneous liquid mixture was poured and flooded into the mold cavity and allowed to cure for 1 day. After 1 day, the cured composite plate was withdrawn from the mold and subjected to post curing for 30min at 100°C. Further, the composite plate after post curing, was kept at room temperature for three to four days. The purpose of Post-curing is to promote the ductility of epoxy composite plate by exposing them to high temperatures after the curing process. After post curing process, specimens were prepared corresponding to ASTM standards to perform various mechanical characterization. Figure 1 shows the systematic process of manufacturing the composite slabs using a casting process and preparation of samples as per ASTM standards. Table 1 shows the notations used for different wt% of duck eggshell while conducting experiments:

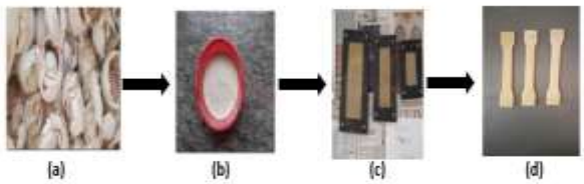

Figure 1. (a) Waste eggshells (b) Fine duck eggshell powder (c) Mixture of resin and eggshell powder (d) Tensile specimens.

III.SPECIMEN NOTATION

Sample	Eggshell powder (ESP) (%wt)	Epoxy resin (ER) (%wt)
1	0	100
2	4	96
3	8	92
4	12	88
5	16	84

IV. MECHANICAL TESTING AND DISCUSSIONS

The characterization of the prepared composites showed that the duck eggshell powder reinforcement is having considerable impact on improved strength of the composite. The results of mechanical tests of duck eggshell powder reinforced epoxy composites fabricated by various weight percentages of reinforcement are presented. It was noticed that the elastic properties of fabricated composite is increasing with the increment of duck eggshell powder content as reinforcement. The tensile, flexural and impact strengths of duck eggshell powder reinforced epoxy composites are more as compared with neat epoxy. The mean values of mechanical properties of three identical samples are tabulated, and the reasons for increase in strengths and ductility are outlined in in detail by means of various graphs for each mechanical/elastic property.

A. Tensile Test

Uniform thickness flat specimens are regularly used for tensile test. Commonly, two kinds of flat specimens are available: rectangular and dumbbell shape. In the current research investigation, specimens with the standard ASTMD 638-III dumbbell shaped specimens are used and loaded in the UTM to perform the tensile test at 10mm/min cross-head speed. The purpose of tensile test is to determine the tensile strength (TS), % elongation and Young's modulus of different composite specimens. A tensile load of 'F' newton is applied at the end points of the composite sample during the test. The specimen loading procedure and computerized UTM utilized for the tensile test are depicted in Figure 2(a). For every composition, three specimens were tested to determine the "TS; the mean result was utilized.

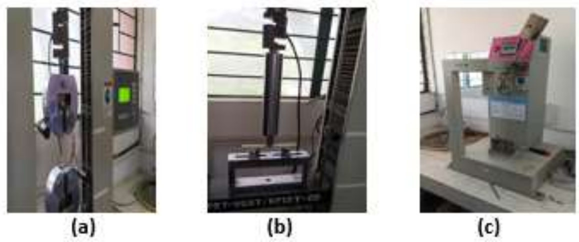

Figure 2. (a) Tensile test sample loading (b) Flexural test sample loading (c) Impact test sample loading.

V. TENSILE TEST RESULTS

Sample	Tensile strength (TS) (MPa)	% Elongation	Young's modulus 'E' (MPa)
1	28.11	6.81	654.84
2	34.72	8.51	709.47
3	40.13	9.04	698.24
4	50.13	10.02	803.79
5	33.57	8.09	698.99

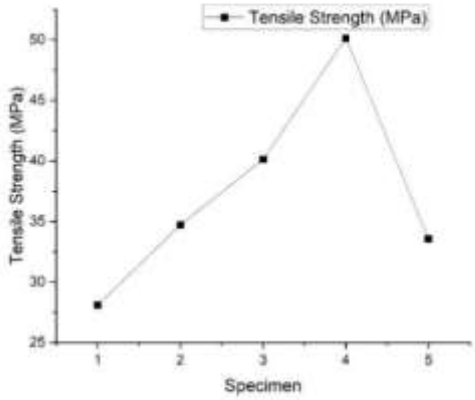

Figure 3. Specimen vs. Tensile strength

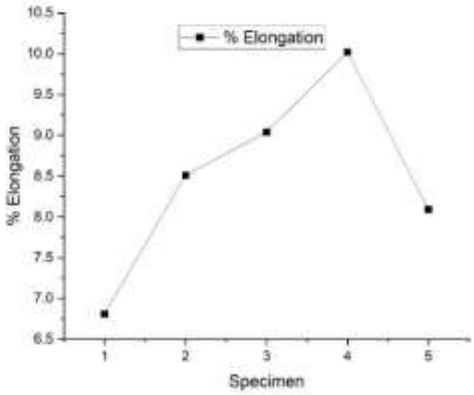

Figure 4. Specimen vs. % Elongation

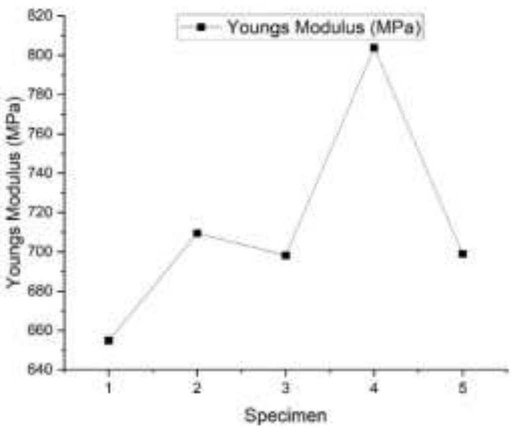

Figure 5. Specimen vs. Young’s modulus

The tensile strength values of all the composite variants are represented in figure 3. In the figure, the tensile strength of composite material is gradually increasing with the increase of eggshell powder percentage. The specimen 4 (12% eggshell powder filled composite) variant exhibited a 59.88% improved strength than specimen 1 (unfilled variant). The least value of tensile strength was observed with the unfilled variant. The incorporation of duck eggshell particles improves the molecular interaction with the epoxy resin leading to increased tensile strength. The higher tensile strength could be due to a transfer of tensile stress from the epoxy to the duck eggshell particles. Additionally, the higher surface area of duck eggshell particles reinforced composite in comparison to the surface area of unfilled variant may be contributed towards better performance.

The variation in Young’s modulus & percentage elongation between all the composite variants is represented in figure 4 and 5. The specimen 4 (12% eggshell powder filled composite) variant exhibited 18.53% and 32.03% higher tensile modulus (Young’s modulus) and percentage elongation in comparison with unfilled variant. The increase in tensile modulus and percentage elongation with the increase of duck eggshell powder content in the epoxy resin shows the improvement in ductility. The increase in the Young’s modulus is owing to the improved stiffness and ductility of eggshell powder filled composites.

B. Flexural Test

Flexural strength or bending strength is a basic mechanical/elastic property that defines a material’s capacity to resist deformation under transverse load and upper limit of tensile strength that it can sustain when bent earlier than breaking. A conventional 3-point bending test, in which the load is supplied at the midway and the sample is supported at two locations. A load is incrementally applied to the sample during the test at 10mm/min cross-head speed by a computerized universal testing machine on a prepared specimen which was fabricated as per ASTM D-790 and has dimensions of 127×12.7×3.2mm. Figure 2(b) illustrates the loading of the flexural test specimen. The test was continued 3 times for each variant, and the mean or average value of the FS was found.

VI. FLEXURAL TEST RESULTS

Sample	Flexural strength (FS) (MPa)	Lateral deflection ‘δ’ (mm)
1	56.18	2.12
2	66.13	2.72
3	73.72	3.91
4	156.49	8.79
5	74.83	3.78

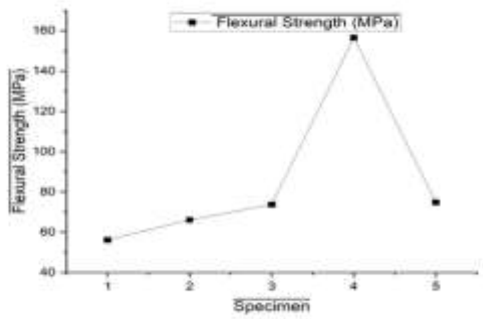

Figure 6. Specimen vs. Flexural strength

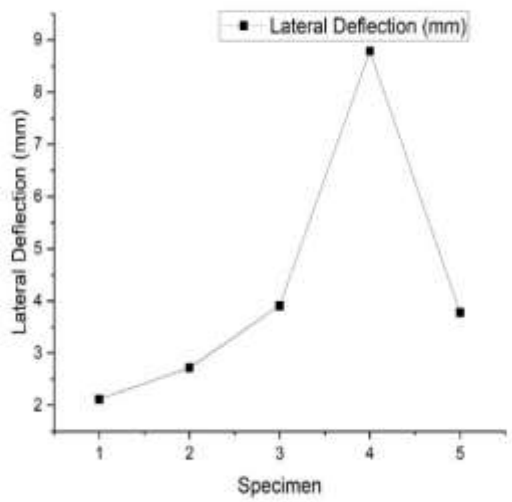

Fig 7. Specimen vs. Lateral deflection

The strength under transverse load (flexural strength) of duck eggshell powder reinforced epoxy composite material is gradually increasing with the increase of Eggshell powder percentage. The graph 6 shows the variation of flexural strength with the increase in percentage of Eggshell powder. In the present study, the specimen 4 (12% eggshell powder filled composite) gives the maximum flexural strength. This is further compared with specimen 1. The flexural strength of specimen 4 is 64.1% higher than specimen 1. From the results, it was noticed that the reinforcement of the duck eggshell powder increases the flexural strength.

The variation of lateral deflection among all the composite variants is depicted in Figure 7. The effect of duck eggshell powder in the specimen 4 (12% eggshell powder filled composite) exhibited a 75.8% higher lateral deflection as compared to unfilled variant. The enhancement in the flexural modulus could be because of the improved stiffness and ductility of duck eggshell filled composites. The integration of duck eggshell particles increases the molecular interaction with the resin leading to increased flexural strength.

C. Izod Impact Test

The Izod impact test was executed according to ASTM-D256 for specimen sizes of 63.5 mm×12.7mm×3.2mm. The intention of the test was to measure the energy absorbed by the prepared composites in J/m. The V-notch was cut at the midpoint of the specimen to a depth of 10 mm. When the pendulum strikes the notched specimen which has been clamped in the impact testing machine clamp, the energy absorbed by the specimen can be immediately noticed from the dial indication of the impact testing machine. Figure 2(c) illustrates the loading of the impact test specimen. The impact strength is represented in Table 4, which shows the average impact strength of three experimental values.

VII. IZOD IMPACT TEST RESULTS

Sample	Izod impact strength (IS) (J/m)
1	4
2	5.6
3	7.2
4	9
5	6.8

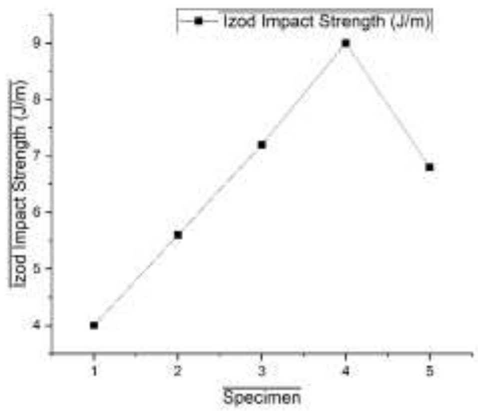

Figure 8. Specimen vs. Izod impact strength

The purpose of impact test is to measure the energy absorbed by all the composite variants in Joules per meter (J/m). The results obtained in the Izod impact test for the epoxy composites reinforced with Eggshell powder along with pure epoxy resin are presented graphically in figure 8. It was noticed that the energy absorbed under impact by all the composite variants is gradually increasing with the increase of Eggshell powder percentage as compared to pure epoxy. Related to the other composite variant, specimen 4 (12% eggshell powder filled composite) appears to have greater energy absorption before fracture. The impact strength of specimen 4 is 55.55% higher than specimen 1. This could be because, the rigid particles of duck eggshell powder chemically combine with the epoxy resin and helps to absorb more energy. Further, there was a significant difference in impact strength values for 12 wt% and 16 wt%. Increase in amount of duck eggshell powder in a composite can increase energy absorption and impact strength. Though, too much duck eggshell powder can decline the elastic properties as a result of the reduction in porosity.

VIII. CONCLUSIONS

Epoxy resin is popularly used in the manufacture of composite material by virtue of its excellent adhesive property and mechanical/elastic properties. In the present study, for the first time, epoxy composite reinforced with duck eggshell powder, was subjected to various tests for mechanical properties. The following conclusions may be drawn from the results:

- In the results of tensile test, the composite with 12% eggshell powder filled presented the maximum tensile strength and percentage elongation.
- The composite Specimen with 12% eggshell powder demonstrated the maximum flexural strength when compared to other composite variants.
- The Izod impact test revealed that the addition 12 wt% of duck eggshell powder resulted in an appreciable increase in impact strength as related to the pure epoxy indicating that the impact strength is directly proportional to the duck eggshell powder content.

Since the bending strength is more compared to tensile strength, the manufactured composite could be used in automotive and aerospace applications.

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REFERENCES

1. Y.T. Yu, M.F. Lau, "A comparison of MC/DC, MUMCUT and several other coverage criteria for logical decisions", Journal of Systems and Software, 2005, in press.
2. Subhrajit Ray, Sourajit Acharya, Prasanta Kumar Barik, “Study on Mechanical Properties of Polymer Composites Filled with Nano Egg-shell Powder”, Archives of Current Research International, 2024, Vol. 24, pp. 360 - 369.
3. Raffi Mohammed, Irfan Anjum Badruddin, Abdul Saddique Shaik, Sarfaraz Kamangar, Abdul Azeem Khan, “Experimental Investigation on Mechanical Characterization of Epoxy-E-Glass Fiber-Particulate Reinforced Hybrid Composites”, ACS Omega, 2024, Vol. 9, pp. 24761 - 24773.
4. Hoo Tien Nicholas Kuan, Ming Yee Tan, Yiou Shen, Mohd. Yazid Yahya, “Mechanical properties of particulate organic natural filler-reinforced polymer composite”, Discover Materials, 2021, Vol. 30, pp. 1 - 17.
5. A.F. Muhammad, M.H Hassan, Z. Mustafa, “Effect of eggshell fillers on the tensile and flexural properties of glass fiber reinforced polymer composites”, Materialstoday, 2022, Vol. 66, pp. 2938 - 2942.
6. Harsimran Singh, N.K Batra, “Development of new hybrid jute/carbon/fishbone reinforced polymer composite”, Materialstoday Proceedings, 2021, Vol. 38, pp. 29 - 33.
7. S. Saravanakumar S, Kapilan P, Ravikumar G, “Rajeshkumar, Effect of fish scale powder addition on the mechanical and free vibration properties of jute/carbon fibers reinforced hybrid polyester composites”, Wiley, 2024, Vol. 45, pp. 9911 - 9918.
8. Ali Mohammed Korsheed., Ghassan Abdul-Hamid Naji, “Preparation and Characterization of Natural Fish Bone as an Implant Material”, Journal of medical and Chemical Sciences, 2023, Vol. 6, pp. 668 - 676.
9. Mailapilli Kumar Raja, K E R V Prasad, A. Prasanna Devi, B A M B A Kumar, A. Aparna Devi, “Unleashing The Mechanical properties of Synthesized HAp (Eggshell) Particulates Reinforced in Biodegradable Polymer Composites”, International Research Journal of Engineering and Technology, 2024, Vol. 10, pp. 1156 - 1157.
10. Chinmoy Kuila, Animesh Maji, Ujjwal Phadikar, Phani Kumar Mallisetty, “Bio-inspired basalt fiber reinforced epoxy laminates with wasted egg shell derived $CaCO_3$ for improved thermal and mechanical properties”, Wiley, 2023, Vol. 45, pp. 215-226.
11. Gondi Konda Reddy, Jayakiran Reddy Esanakula, “Mechanical Characterisation of Fibre-Reinforced Composites with Eggshell Powder for Diverse Applications”, Springer, 2024, pp. 343–351.
12. L.M. Hasan, A.M. Ali, “Assessment of eggshell and CaCO3 reinforced recycled aluminium green metal matrix”, Journal of Achievements in Materials and Manufacturing Engineering, 2024, Vol. 118, pp. 57–61.
13. Anjali, Razia Malik, Shivani Bhandari, Ankur Pant, Arpit Saxena, “Fabrication and Mechanical Testing of Egg Shell Particles Reinforced Al-Si Composites”, International Journal of Mathematical, Engineering and Management Sciences, 2017, Vol. 2, pp. 53–62.
14. Kalkidan Gossaye, Kiran Shahapurkar, Venkatesh Chenrayan, Ibrahim M. Alarifi, Compressive behavior of Habesha eggshell particulate reinforced epoxy composites, Wiley, 2023, Vol. 44, pp. 562-573.
15. P. E. Emumejaye, S. C. Ikpeseni, P. O. Ohwofadjeke, S. O. Sada, “Characterization of Eggshell Reinforced Aluminium Composites”, Nigerian Journal of Technology, 2024, Vol. 43, pp. 685-695.
16. Anahita Homavand., Anahita Homavand, Lee D. Wilson, “Polylactic Acid Composites Reinforced with Eggshell/CaCO 3 Filler Particles - A Review”, MDPI, 2024, Vol. 2, pp. 169–185.

17. Iti Dikshit., Gian Bhushan, 2022, "Development of an innovant carbon/jute porcine-bone hybrid material for sustainable composite manufacturing", Wiley, Vol. 3, (2022) 2419-2430.