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Epoxy resin based egg shell powder and coconut coir fiber composites

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Abstract - *This research project was started with the collection of eggshells which were discarded as waste and were collected, treated and crushed into flakes of around 0.5 to 5mm in size and half amount of flakes was powdered into particle size about (60 to 70µm). Coconut coir fibers were also extracted from the raw coir and chopped upto 10 mm in length. The composites were prepared by resin casting process which was started with making mould out of white cement which was further used for casting. The test specimens for izod,tensile and flexural test were prepared. Epoxide resin and hardener were mixed in the ratio of 2:1 then reinforcements were added composition wise and poured in the mould and for 24 hours cured at room temperature. After curing the specimens were tested for tensile, flexural and izod impact strength according to the ASTM standards. The results in digital form were obtained on the display of PC then analyzed and compared. Results show that, the tensile strength was obtained slightly higher in Epoxy + Coir composite than hybrid, flexural and izod impact test found higher in hybrid composites. So from this experiment it was concluded that the strength of composite depends on coir fiber and impact strength of composite depend on both the reinforcements (coir fiber and egg shell flakes).*

***Key Words*: Epoxy resin, coconut coir ,egg shell powder , natural fiber composites , calcium carbonate .**

1. INTRODUCTION:

Many applications in automotives require materials with a combination of properties that cannot be obtained from conventional metal alloys. They are neither degradable nor recycled. They are thus replaced by composites. Natural fiber composites are low in density and ecological advantages, non-carcinogenic and bio-degradable in nature as compared to conventional composites. Major applications of composites are in aircrafts, transportation vehicles ,construction, sports goods , packaging etc. They exhibit good corrosion resistance, ,good resistant to extreme temperatures and wear resistance especially in industrial sectors. FRP is a composite material with fibers such as glass, aramid and carbon which have high strength. Matrix and reinforcement are the two constituents that make a composite which remain separate and distinct within the composite. The matrix material supports the reinforcement materials by maintaining their relative positions. The reinforcements impart special mechanical and physical properties to the matrix material. The composites strength will vary depending upon the composition of the two constituents.

Composite: It is made by combining fibers and binder or 'matrix' which consolidates the fibers in place.

Properties of composites: Glass fibers are being replaced by natural fibres, due to their low cost, high strength-to-weight ratio, and capable of being recycled .

Reinforcement: The reinforcement enhance the mechanical properties of the resin system. Properties of the composite depend upon which reinforcement is used as each have distinct properties .

In this project epoxy resin was used as the matrix to consolidate the reinforcement. Epoxy resin is a two component system consisting of resin (A) and hardener (B). Both A and B are mixed in the ratio of 2:1 sometimes 1:1 ratio also used. Hardener used maybe anhydride, amine, aliphatic or cycloaliphatic based. Epoxy resins have more than one 1,2- epoxide groups per molecule. Curing is achieved by introducing curing agents that react with epoxy and hydroxyl groups situated on adjacent chains.

Egg shells waste is less in cost , plentiful in nature and has a structure with intrinsic pore and thus used nowdays in large amount . Eggshell constitutes about 11% of the total weight of the whole egg and contains about 91% of $CaCO_3$. Reports say that 1,90,000 tons of eggshell is wasted in India and might be used in human nutrition as a calcium source. They consists of protein lined along with calcium carbonate which suits perfect for bulk quantity in cheaper rates, and articles for lightweight and low load bearing applications in domestic as well as in transportation sector.

Coir, or coconut fibre, is a naturally occurring cellulosic fibre extracted from the outer husk of coconut and used in floor mats, doormats, brushes and mattresses. Coir is the fibrous in nature found between the hard, internal shell and the outer coat of a coconut. These fibers have high tensile strength that is why they are mostly used to manufacture the ropes and in demand because of its biodegradability .Because of its strength and biodegradable nature it is an emerging material in research and development in composite sector which is being used in furniture, interior designing and construction industry.

EXPERIMENTAL WORK DONE:

Materials:

Epoxy resin with hardener (Aliphatic) was used as matrix procured from Chemocrat Sales Pvt. Ltd., Pune and for

reinforcement we used coconut coir fibers, egg shell (flakes), egg shell (powder) and $CaCO_3$ taken from college laboratory. We used white cement for the preparation of moulds for casting and was procured from local seller. All these materials were used to prepare the composites with different composition for further comparison.

Fig 1: a) Epoxy resin b) Egg Shells c) Coconut Coir d) $CaCO_3$

3.2.**Preparation Methods:**

The process of preparation of the composites starts with the pre-processing of the egg shells and coconut coir, then preparation of the mould out of the white cement and at the end the preparation of composites by casting. The preparation is explained below in detail.

1) Preparation of egg shell flakes and powder:

Preparation of egg shell flakes starts with washing with water and removal of inner layer of the egg then washing again for cleaning in water. After that we kept egg shells dipped in 7% conc. NaOH solution for the removal of microbes. Then it was again cleaned with water and then sun-dried. The flakes were made by randomly crushing with hands having the size ranges from 0.5 mm to 5 mm. Powder from egg shell was prepared by grinding it in mortar and pestle set and the grain size achieved was around 60 to 70 microns.

Fig 2: Egg shells to flakes and then into powder (left to right)

2) Preparation of coconut coir fibers:

Preparation of coir fibers started by the hammering the dry raw coconut coir for the removal of waste particles of husk attached with the coir fibers. Then the pure coir fibers were obtained and further chopped upto 10 mm in length with the help of scissor.

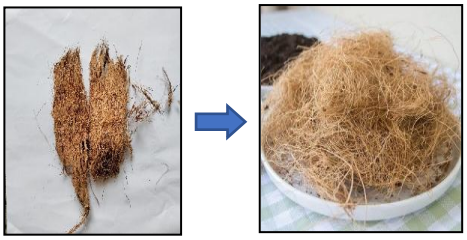

Fig 3: Raw coconut coir to coir fibers (left to right)

3) **Preparation of moulds**:

For making the moulds initially we made a tray out of the PET films by folding its edges and stapling. Then we placed pre-moulded test specimens in the tray for making the cavity and were coated with release agent for easy removal. Then we poured the slurry consisting of white cement and water onto the specimens and remaining part of the tray and kept for curing. And it had taken upto 12 hours for total curing of the white cement, thereafter we removed the specimens and the mould was ready with impressions having the shape of test specimens (tensile, flexural and izod impact) to cast the epoxy resin with reinforcements to prepare the test specimens for tensile, flexural and izod impact test. Two moulds were prepared with the same method.

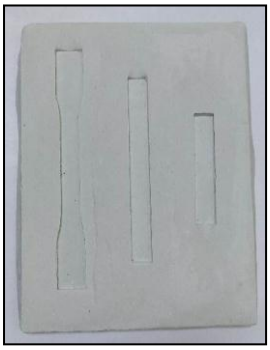

Fig 4: Mould made of white cement for casting

4) Preparation of composites:

The composites were prepared by casting method.A mixture of epoxy resin and hardener were taken in the ratio of 2:1. Then the reinforcement was added to the epoxide resin and stirred for a minute to achieve proper mixing. Until the mixing procedure was carried out side by side the release agent was applied in the cavities of the mould. Then the resin mixture was poured into the cavity and kept for curing at room temperature for 24 hours. After 24 hours all specimens were cured and hardened but composite with $CaCO_3$, egg shell powder and flakes remained flexible. We tried to harden those specimens by heating them in oven at 65°C

for 45 min. but it was unsuccessful. Thereafter although the samples were flexible we used them further for testing along with other specimens. The composites specimens were prepared with the different compositions are given in table no.

- Composition Nomenclature:

  Raw Epoxy (C1)

  Epoxy + $CaCO_3$ (C2)

  Epoxy + Egg Shell Powder (C3)

  Epoxy + Egg Shell Flakes (C4)

  Epoxy + Coir Fibers (C5)

  Epoxy + Coir Fibers And Egg Shell Flakes - Hybrid (C6)

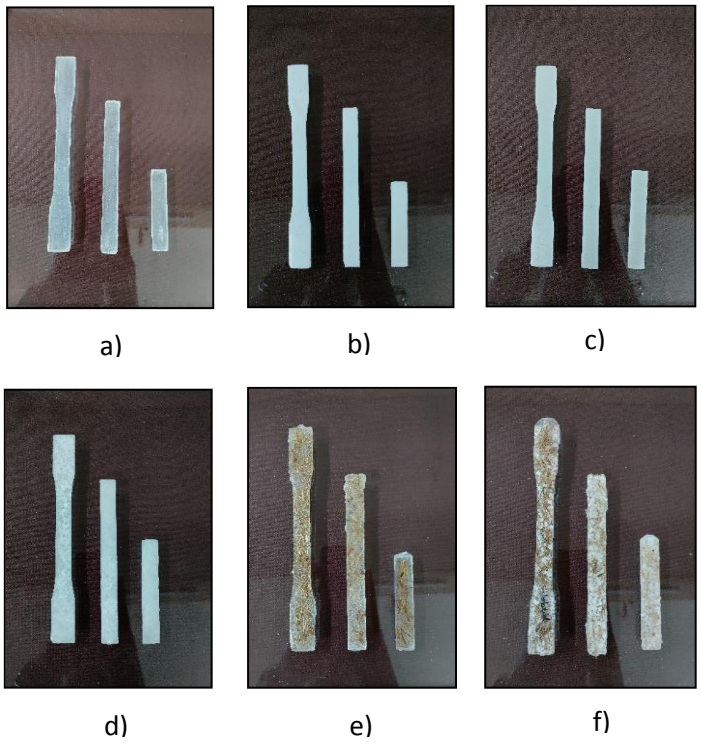

Fig 5: Test specimens – Tensile, Flexural & Izod impact test
a) Raw epoxy b) Epoxy + $CaCO_3$ c) Epoxy + Egg shell powder d) Epoxy + Egg shell flakes e) Epoxy + Coir f) Epoxy + Coir + Egg shell flakes

Reinforcement (%)	Compositions					
	C1	C2	C3	C4	C5	C6
$CaCO_3$	-	30	-	-	-	-
Shell Powder	-	-	30	-	-	-
Shell Flakes	-	-	-	30	-	20
Coir	-	-	-	-	10	10

Table 1: Composition of composites with different reinforcements

3.3.**Testing:**

Note: the testing of raw epoxy specimen was carried out just for the reference and comparison with the other specimens.

i. Tensile test

A Universal Testing Machine (UTM) was used using tensile grips. Tensile strength was determined for each composition according to ASTM D638.

Fig 6. Universal Testing Machine (UTM) with tensile grips

- **Crosshead speed:**

  50 mm/min

- **Specimen dimensions:**

  165 × 13 × 3.2 mm

- **Test conditions:**

  Temperature: 23 ± 2°C
  Humidity: 50 ± 5 %

- **Test procedure:**

  1. Dumbbell shaped test specimens made by injection molding were loaded into the grips of UTM .

  2. Specimen dimensions were fed into the machine software.

3. Then the test was started. The grips pulled the specimen at a constant rate until it breaks.

4. Readings for tensile strength, elongation and tensile modulus were noted down and the test ended after the sample broke.

ii. Flexural test

Flexural test was also performed on UTM by using flexural test fixtures. It was carried out according to ASTM D790 to determine flexural strength.

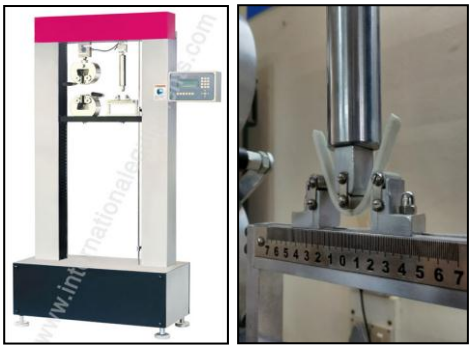

Fig 7. Universal Testing Machine (UTM) with flexural fixtures

- **Crosshead speed:**

  2 mm/min

- **Specimen dimensions:**

  3.2 × 12.7 × 127 mm

- **Test procedure:**

1. Rectangular shaped specimen was fixed on the support span of the UTM.

2. Then entered the specimen dimensions in the software and initiated the test by clicking "Start" button.

3. Then load was applied to the centre by the loading nose producing 3-point loading at a specified rate.

4. Test was stopped when the specimen was broken down.

5. Then readings for flexural strength and flexural modulus were noted down and ended the test.

iii. Izod impact test

Izod impact test was performed on a Izod Impact Tester Machine equipped with izod impact fixtures (vice). It was carried out to determine the impact strength according to ASTM D256.

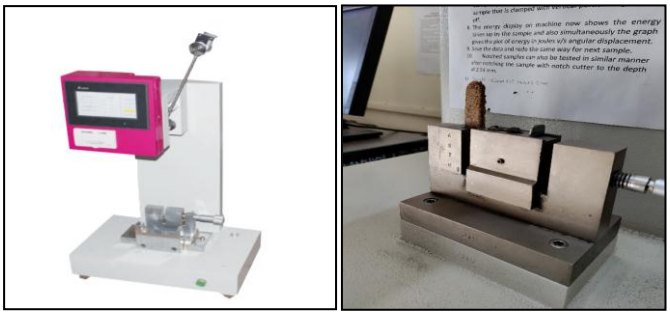

Fig 8. Izod impact tester with izod impact fixture (vice)

- **Specimen dimensions:**

  64 x 12.7 x 3.2 mm

- **Notch dimensions**:

  2.5 mm

- **Test procedure:**

1. Test specimen was clamped vertically into the fixtures with the notched side facing the striking edge of the pendulum.

2. Then specimen dimensions were entered in the software.

3. Pendulum was released and stroked on the specimen.

4. Striking results in breaking of the specimen after that, readings were displayed on the screen.

5. Then result for impact strength was noted down specimens were tested and their average was taken as final reading.

3. RESULTS AND DISCUSSION

Test	Raw Epoxy	Epoxy + $CaCO_3$	Epoxy + Egg Powder	Epoxy + Egg shell Flakes	Epoxy + Coconut Coir	Epoxy + Coconut Coir + Egg Shell flakes
Tensile Strength (N/mm^2)	40.422	3.27	7.395	5.182	43.41	29.958
Flexural Strength(N/mm^2)	52.683	0.48	2.624	2.666	58.763	46.007
Impact Strength (j/m)	57.1	11.4	20	22.4	22.8	97.1

Table 2: Test results showing tensile, flexural and izod impact test result values obtained for various compositions.

4.1.Tensile Properties:

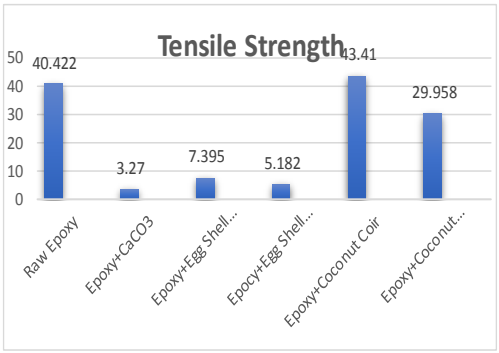

Fig 9: Graphical representation of tensile test data for all composition

The above data of tensile strength shows that the highest strength is in the epoxy + coconut coir because the bonding between matrix and the reinforcement is much better than the other compositions. In the hybrid composite it is observed that the addition of the egg shell flakes affected the tensile properties because of the irregular shape of the egg shell flakes. The composition in which the reinforcement is in the form of powder and flakes it is noted that the tensile properties got reduced because after the whole curing of the composite sample was observed to be flexible.

4.2.Flexural Properties:

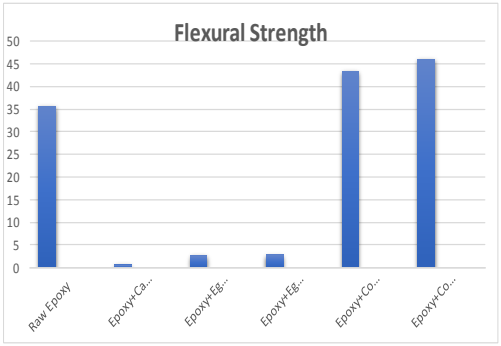

Fig 10: Graphical representation of flexural test data for all composition

The Flexural strength variation of different composition of composite material is illustrated in the above graph. It is evident from the data that the Hybrid Composite (Epoxy + coconut coir + egg shell flakes) is having greater flexural strength as compared to others. Because of the longitudinal orientation of the coir fibers which distributed the load throughout the specimen so it has the ability to sustain the load. In addition to coir there was flakes also available which helped in the distribution of the load.

4.3.Impact Properties:

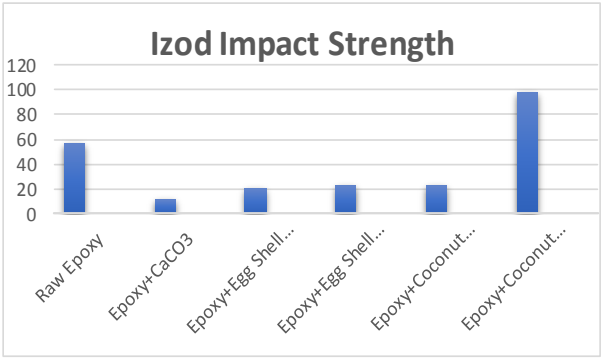

Fig 11: Graphical representation of izod impact test data for all composition

The above data shows the variation of impact strength in the different composition of composite material. It is observed that the hybrid composite is having the highest impact strength because of the bonding strength between fiber and eggshell with the matrix material is excellent. The composite's main purpose is to sustain more load at low weight ratio. The longitudinal orientation of the coir mostly had a great role in increasing the impact strength of the material. But in the other composition it is noted that the impact strength is not that much good because of the flexibility of the specimen.

Comparison of composites with $CaCO_3$ and with egg shell powder:

This comparison was done because the egg shell is made of $CaCO_3$ and we turned it into powder form to compare with $CaCO_3$ in powder form to compare the strength achieved by composite filled with $CaCO_3$ and the egg shell powder which is also made of $CaCO_3$.

Comparing the test results of these two materials it can be seen that, egg shell powder filled composite is better than $CaCO_3$ filled composite. Egg shell powder filled composite achieved higher properties in tensile, flexural and Izod impact test.

4. CONCLUSIONS

The mechanical behaviour of the composite material was studied . Different compositions were mixed consisting of resin and hardener and reinforcements and made into geometrical shapes. They were tested experimentally for impact, flexural and tensile tests. The highest impact strength was observed in the hybrid composite because of the excellent bonding strength between the coconut coir and egg shell flakes with the resin. The flexural strength was also observed to be good in the hybrid composite because the longitudinal orientation of the coir fibers distributed the load through out the specimen as well as the egg shell flakes also helped to distribute the load. In the tensile test, the tensile strength of the hybrid composite was slightly reduced because of the addition of egg shell flakes having irregular geometric shape. But in the composite (Epoxy + coconut coir) the tensile strength was noticed high because of the bonding between the matrix material and fiber was quite good as compared to others. Another comparison was between the composites with $CaCO_3$ and egg shell powder, in this comparison it was found that the higher strength obtained in egg shell powder filled composite than $CaCO_3$ filled composite this maybe happened because of the difference in the particle size of both powders. The composition in which the reinforcement is in the form of powder & flakes was noticed that having very low result as compared to others because the specimen formed were flexible and not having that much strength to sustain the loads. So from this experiment we conclude that the flexural strength of composite depend on coir fiber and impact strength of composite depend on both the reinforcements (coir fiber and egg shell flakes). The purpose of using coconut coir and egg shell flakes was that it was the wastage material which does not have any further application and that is why to reduce this wastage we used these materials as reinforcements with polymer matrix for making the composites which somewhat reduced its cost and to study the effect of addition of these materials on the mechanical properties of composites we carried out this research project.

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