Impact behavior of pine needle fiber/pistachio shell filler based epoxy composite

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Abstract. Natural filler/fiber based composites are material focusing on the use of natural reinforcement material for fabrication process. In present research two different composites are developed using (i) pine needle fiber and epoxy (ii) pistachio shell filler and epoxy. Impact strength of developed composites is studied which shows that with addition of pistachio shell filler and pine needle fibers in composites, there is increase in impact strength as compared to neat epoxy sample. In addition, hybrid composite with natural filler and pine needle fiber has shown the highest impact strength of 23.33 kJ/m². Investigating samples further in different conditions (petrol, kerosene, water) for impact strength, research shows that there is substantial decrease in strength in comparison to the samples subjected to ambient conditions.

Keywords: Pine needle fiber, pistachio shell filler, epoxy, impact test, hybrid composite.

1. Introduction

Sustainable use of natural resources is demand in recent years which is enforcing researchers to make use of natural reinforcement for making composite materials. Composites constitute of two or more material macroscopically combined to contribute a range of attributes that uniquely material does not possess. Combined materials retain their own properties which make composites to create more value in term of properties [1]. Use of natural materials for fabrication of composite from rice husk, walnut shell, groundnut shell, cashew nut, bamboo fiber, jute fiber [2-7] etc. has been conducted by researchers in the past years. Health, economic, environmental, bio waste management, biodegradability and reduced energy consumption are the concern areas which are successfully tackled by the natural composite materials [8]. In this article study of impact test on composite with different reinforcement in form of particulate, laminated fiber and a combination of laminated and particulate are discussed. Pine needle fiber are produced as bio-waste by Pinus roxburgii plant, having the ability to act against cancer tumors [9], DNA damage [10] and antibacterial ability [11]. Thakur et al discussed on the mechanical analysis of pine needle reinforced composites with the latex as the resin and chopped fibers (3 mm and 6 mm) as the reinforcement [12]. Bhandari et al conducted the tensile test on pine needle fibers and investigated the tensile strength (35.8 MPa) of individual fiber using the tab method [13]. Marhoon investigated the properties of pistachio shell filler with polyurethane matrix and showed the effect of filler on tensile strength, impact strength and hardness with different weight fractions (2.5%, 5%, 7.5%, 10%) [14]. Problems occur when combining the natural fillers or fibers with polymer resin of which incompatibility of polymer with water is one of the
major concern. Natural fibers are hydrophilic while polymers are hydrophobic in nature [15]. Drying and pre-heating of the pine needle fibers and pistachio shells is done to remove the absorbed moisture from the atmosphere. Improving the bond strength among the reinforcement and matrix favors high degree of impact strength and improves the resistance towards high impact blows [16].

2. Experimental

2.1 Materials

Epoxy LY 556 and hardener HY 951 were used for sample preparation. *Pinus roxburgii* plant fibers (also known as Himalayan pine needle tree shown in figure 1) and Pistachio shell (figure 2) particulates are used as the reinforcement. Concentration of the epoxy and hardener was in ratio of 10:1. 10% concentration of pistachio shell filler was used for the research with epoxy-hardener mixture. Pine needle fiber were added in 20% by weight in epoxy-hardener mixture. Properties of material used is enlisted in the table 1.

| Table 1:– Properties of Epoxy [17] and hardener [18] |
|------------------------------------------------------|
| **Araldite LY 556** | **Hardener HY 951** |
| Physical state | Liquid | Liquid |
| Viscosity at 25 °C (ISO 9371B) [mPa s] | 10000 - 12000 | 10-20 |
| Density at 25 °C (ISO 1675) [g/cm³] | 1.15 - 1.20 | 0.9 |
| Flash point (ISO 2719) [°C] | > 200 | 110 |
| Storage temperature[°C] | 2 - 40 | 10-40 |

2.2 Sample Fabrication

The composite specimens were fabricated with pine needle fibers and pistachio shell fillers using hand lay-up technique. Fibers were collected from the hilly terrain areas of Uttarakhand. Heating of the mat is done
to remove the absorbed moisture. The mats were dried at 80°C for 5-6 hrs in a hot air oven (Aimil Ltd. Instrumentation & Technologies). Alternate layers of the epoxy resin and mats were placed and roller was used to remove the entrapped air during the fabrication process. A load of 30 N was placed over the mold to apply suitable pressure. Samples were left for 24 hrs at atmospheric temperature of around 24°C to cure.

Pistachio shells were dried in hot air oven at 100°C for 24 hrs. Dried pistachio shells were grinded in a kitchen grinder (eco plus manuf. 500 W power ) and passed through sieve to obtain particles of size 300µm-500µm. Pistachio shell sample were prepared by using mold of size 200*200*5 mm³. Pistachio shell particles were dried before preparing the samples at 50°C for 3-4 hrs to remove any absorbed mixture.

Dried shell fillers were mixed thoroughly with epoxy resin by stirrer for 15-20 min to achieve uniform mixing. Hardener was added to filler resin mixture and mixed for 15 min till sign of increased temperature was observed. Mixture was poured in glass mold and sample was left for 24 hrs to cure at room temperature condition. Sharp pin was used to burst the air bubble coming to the surface of the sample. Samples with three different specifications are coded in the following table 2.

Table 2:- Samples with different specification

| S.no. | Samples | Specification                              |
|-------|---------|-------------------------------------------|
| 1.    | S₁      | Neat Epoxy                                |
| 2.    | S₂      | Reinforced with pistachio shell filler of 10% concentration |
| 3.    | S₃      | Reinforced with pine needle fiber 20% concentration |
| 4.    | S₄      | Reinforced with combination of 10% filler and 20% fiber |

2.3 Analysis and Testing

2.3.1 Charpy Impact Testing

Impact Testing Machine (AIT-300 D) was used to test the impact strength of the composites. Samples were clamped in the machine and test were carried out with different samples. Impact properties of polymer based composite mainly depends on the toughness of the material and toughness of any material is defined as the ability to absorb energy before fracture. There are two methods namely Izod and Charpy used in impact test. In Izod method the specimen is held vertically like as cantilever beam and in Charpy method the specimen is held horizontally like simply supported beam. Charpy method was used in the paper to get the impact strength. Figure (5) shows the Charpy impact machine and figure (3, 4) shows specimen with standard dimension. Each sample is subjected to three different environment condition in water, petrol, and kerosene. For each sample, three specimen were prepared to ensure the validation and test in impact testing machine.
2.3.2 Water Absorption Test

Water absorption test was performed of $S_1, S_2, S_3,$ and $S_4$ as per ASTM D-570 standards. Electronic balancer was used to measure the weight of the samples before and after absorption of water. Cycle gap of 48 hrs was given between each measurement of weight. Fraction change in the weight of samples is also measured and shown in the table 3.

3. Results and Discussion

It was observed that by adding pistachio shell filler by 10% the impact strength of $S_2$ increased by 36.5% in comparison to $S_1$, addition of pine needle fiber increase the impact strength of $S_3$ by 32.5% in
comparison to neat epoxy (S1) and decreased by 2.9% in comparison to S3, further addition of pistachio shell fillers with pine needle fibers resulted in increase of impact strength of S4 by 40.5% in comparison to S1 and increased by 6.04% in comparison to S3. It is concluded that the reinforcement add the specific required properties to the epoxy thus increasing in its resistance to the fracture. Further, accounting the results graph shows that for the S4 impact strength was 23.33 kJ/m² which is highest among all the samples. There can be two probable reasons for this: (1) the filler added filled the voids in the S3 thus increasing the bonding between resin and reinforcement, (2) filler based epoxy resin (behaves like a bio-resin) as matrix has more of similar characteristics (natural fibers are derived from lignocellulose [18]) like the fiber mats as compared to the neat epoxy resin. When samples were dipped in different liquids (water, petrol, kerosene) for 7 days and impact strength was done there is decrease in strength. Different liquid was absorbed by the sample which decreased the resistance towards the impact blows thus, leading to early failure of the samples. Contrary to S1 and S4, S2 absorbed less liquid so there is less change (0.22 % decrease) in the strength and line graph is almost overlapping comparing to ambient conditions.

**Table 3:-** Water absorbed by the samples

| Sample | Weight (grams) | 0 | 24 (hrs) | % change | 72 (hrs) | % change | 120 (hrs) | % change | 168 (hrs) | % change |
|--------|----------------|---|----------|-----------|----------|-----------|-----------|-----------|-----------|-----------|
| S1     | 2.2            | 2.2 |         | 2.2       |         | 2.2       |         | 2.2       |         | 2.2       |
| S2     | 2.4            | 2.43 | 1.25    | 2.466    | 2.75    | 2.466    | 2.75    | 2.466    | 2.75    |
| S3     | 3.71           | 3.83 | 3.23    | 3.933    | 6.01    | 3.933    | 6.01    | 3.966    | 6.9     |
| S4     | 3.3            | 3.5  | 6.06    | 3.533    | 7.06    | 3.533    | 7.06    | 3.566    | 8.06    |

**Table 4:-** Impact Strength of samples

| Specimen | Average Impact Strength(kJ/m²) |
|----------|--------------------------------|
|          | Ambient | Water | Petrol | Kerosene |
| S1       | 16.60   | 16.62 | 16.61  | 16.60    |
| S2       | 22.67   | 19.12 | 22.72  | 22.64    |
| S3       | 22.00   | 16.41 | 19.62  | 17.72    |
| S4       | 23.33   | 16.89 | 16.16  | 16.20    |
4. Conclusion

In this study, pine needle fibers and pistachio shell fillers were incorporated in epoxy to develop composite. The pistachio shell fillers were added in 10% by weight. The developed epoxy composites were subjected to different environmental conditions i.e. water, petrol and kerosene. The impact strength of the developed composite specimens were evaluated. It is concluded that the specimens tested in ambient conditions showed better impact strength compared to the samples immersed in water, petrol and kerosene. S4 sample showed strength of 23.33 kJ/m² with an increase of 40.54% than neat epoxy. Decrease in strength by 27.60%, 28.84%, and 30.56% is seen when sample was subjected to water, petrol, and kerosene respectively.

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