Mechanical behavior of glass fiber polyester hybrid composite filled with natural fillers

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Abstract. Now-a-days, the natural fibers and fillers from renewable natural resources offer the potential to act as a reinforcing material for polymer composite material alternative to the use of synthetic fiber like as; glass, carbon and other man-made fibers. Among various natural fibers and fillers like banana, wheat straw, rice husk, wood powder, sisal, jute, hemp etc. are the most widely used natural fibers and fillers due to its advantages like easy availability, low density, low production cost and reasonable physical and mechanical properties. This research work presents the effect of natural fillers loading with 5%, 10% and 15% on mechanical behavior of polyester based hybrid composites. The result of test depicted that hybrid composite has far better properties than single fibre glass reinforced composite under impact and flexural loads. However it is found that the hybrid composite have better strength as compared to single glass fibre composites.

1. Introduction

The growing demand in the world for more adaptable materials suitable for various applications led to the development of polymeric composites with synthetic fibers as reinforcing agents. Synthetic fibers are not environment friendly because its create environmental pollution so this has shifted the focus on utilizing natural fibers, capitalizing on their advantages of being environment friendly, economical, lower densities, higher filling levels, environment friendly and renewable nature, recyclability [1-3]. Natural fibers can be used as alternatives of synthetic fibers, e.g. aramid, glass, carbon, etc. [4]. Natural fibers such as bagasse [5, 6], jute [7, 8], hemp [9], banana [10-14], rice husk [15-21], corncob [22], luffa [23] etc. have satisfactory mechanical properties make them an attractive ecological alternative to synthetic fibers used for the manufacturing of composites [4]. Natural fibers have superior mechanical properties such as flexibility, stiffness and modulus compared to glass fibers [25]. The natural fibers such as banana, rice husk, luffa, sisal and jute fibers are replacing the glass and other synthetic fibers because it’s have easy availability and cost [28]. Banana/rice husk fiber composites are environment friendly and user-friendly materials and have very good elastic properties. Banana fiber is the best reinforcement because of low cost, low density, high specific strength, no health hazards and finding applications in making of ropes, mats, carpets, fancy articles etc. In
addition to this, adding banana, rice husk, sisal, jute palm etc. fibers with glass fiber improves thermal properties, mechanical properties and water resistance of the hybrid composites [24, 25]. Rice husk contains 75-90% organic matter such as cellulose, lignin etc. and rest mineral components such as silica, alkalis and trace elements [30]. Rice husk is unusually high in ash compared to other biomass fuels in the range 10-20%. The ash is 87-97% silica, highly porous and light-weight, with a very high external surface area. Presence of high amount of silica makes it a valuable material for use in industrial application [31]. Other constituents of Rice Husk Ash (RHA), such as K2O, Al2O3, CaO, MgO, Na2O, Fe2O3 are available in less than 1%. Rice husk having bulk density of 96-160kg/m³, oxygen 31-37%, nitrogen 0.23-0.32%, sulphur 0.04-0.08% [32]. It is noted that cellulose is the main constituent of plant fibers followed by hemicelluloses and lignin interchangeably and pectin respectively. Cellulose is also the reinforcement for lignin, hemicellulose and Pectin. Banana fibers have 60-65% cellulose, hemicellulose 6-19%, lignin 5-10%, pectin 3-5%, ash 1-3% [10].

Yiping Qiu et al [26] state that hybrid composites have two or more types of reinforcement which can provide better mechanical properties and reduce the cost of the composite material by mixing reinforcements such as glass fibers with more expensive high-performance fibers. K. Sabeel Ahmed et al [27] describe that natural fibers such as jute, sisal, banana, bamboo, etc. offer several advantages over conventional fibers such as glass, carbon, graphite, kevlar, etc. The advantages are low density, low cost, good thermal and insulating properties, renewability, bio degradability, high specific strength, etc. Hazizan Md. Akil et al [29] study that pultrusion is in principle a suitable process for fabrication of jute and kenaf fiber composites and their hybrids with glass fibers. Its successful implementation for large volume production would need some optimization.

2. Experimental details

2.1. Materials required

Banana and rice husk fillers were collected from local resources of sharanpur, uttar Pradesh, India. The secondary reinforced E-Glass fiber chopped strand mat was collected from M/s. Amtech esters Pvt. Ltd. New Delhi, India. Unsaturated isophthalic polyester resin of commercial grade VBR 4503 was used as the resin. Methyl ethyl ketone peroxide (MEKP) and cobalt naphthenate were used as curing catalyst and accelerator. The polyester matrix, catalyst and accelerator were also supplied by M/s. Amtech esters Pvt. Ltd. New Delhi, India.

2.2. Fabrication of hybrid composites

The fabrications of composite slab are carried out by conventional hand layup technique [33]. E-glass chopped strand mat are used as reinforcement and polyester resin is taken as matrix material with natural fillers (banana fiber, rice husk). The low temperature curing polyester resin, hardener and accelerator are mixed in a ratio of 100:1.5:1.5 by weight percentage [34, 35]. A plywood mould having dimension of (310×210×20) mm³ is used for composite fabrication. The natural fillers are mixed with polyester resin by the simple stirring and the mixture is poured into various moulds conforming to the requirements of various testing conditions and characterization standards. The composite samples of different compositions with different weight percentage of fillers were prepared. A releasing agent is used for facilitate easy removal of the composite from the mould after curing. If any entrapped air bubbles are there, then they are removed by a sliding roller and the mould is closed for curing at a room temperature for 24 h at a constant load of 25-30kg. After curing the specimens of suitable dimensions are cut for mechanical test as ASTM standard. The composition and designation of the composites prepared for this study are listed in Table 1.
Table 1. Detailed designation and composition of composites.

| S. No. | Composites | Compositions                          |
|--------|------------|---------------------------------------|
| 1.     | C1         | Glass fiber(20 wt%) + Polyester       |
| 2.     | C2         | Glass fiber(20 wt%) + Banana chopped filler (5 wt%) + Polyester |
| 3.     | C3         | Glass fiber(20 wt%) + Banana chopped filler (10 wt%) + Polyester |
| 4.     | C4         | Glass fiber(20 wt%) + Banana chopped filler (15 wt%) + Polyester |
| 5.     | C5         | Glass fiber(20 wt%) + Rice husk filler (5 wt%) + Polyester |
| 6.     | C6         | Glass fiber(20 wt%) + Rice husk filler (10 wt%) + Polyester |
| 7.     | C7         | Glass fiber(20 wt%) + Rice husk filler (15 wt%) + Polyester |

3. Mechanical properties of composite materials

3.1 Tensile test

The tensile test is done by cutting the composite specimen as per ASTM: D3039-76 standard. A universal testing machine with maximum load rating of 400 kN is used for testing. Seven different composite specimens with different filler loading combinations of GFRP are tested, which are shown in Fig. 4. In each case, two samples are tested and the average is determined and noted. The specimen is held in the grip and load is applied and the corresponding deflections are recorded. Load is applied until the specimen breaks and break load, ultimate tensile strengths are noted.

![Figure 1. Specimen prepared for tensile test.](image)

3.2 Flexural Test

The Flexural test is done in a three point flexural setup as per ASTM: D790-03 standard. The specimen (Fig. 2) bends and fractures when the load is applied at the middle of the beam. This test is carried out in the universal testing machine from which the breaking load is noted and then calculates the flexural strength of all samples.
3.3 Charpy Impact Test

As per using an impact tester the impact tests are done on the composite samples. Charpy impact test was carried out in VeeKay (Model-I91) machine in accordance with ASTM E23 to measure the impact strength of the composites. The pendulum impact testing machine determines the notch impact strength of the material by devastating the V-notched sample with a pendulum hammer, calculating the impact strength. The standard sample size is 55 × 10 × 10 mm and the depth of the notch is \((t/3=3.33 \text{ mm})\) 6.66 mm of the notch. The scale of the machine is 1 division = 2 joule. Specimens for charpy impact test shown in fig.3.

3.4 Hardness Test

As per using hardness tester the hardness tests are done on the composite samples. Hardness test (BHN) was carried out in a vickers cum brinell hardness testing machines (Model: BV-250) machine to measure the hardness of the composites. Range of test loads for Vickers / Brinell test are from 1 kg to 250 kg. Optical Magnifications is available in 35X, 70X & 140X. A precision Diamond Indentor (136° pyramid) is used to make sharp indentations on the specimens / samples. Load accuracy is well within ± 1% of nominal load value. Diameter of indent will be displayed on computer monitor automatically and results find out from the table. For the brinell hardness test load available are 15.625, 31.25, 62.5, 187.5 and 250 kg. A load of 2.58N was applied on the flat surfaces of the samples for 15 seconds to calculate the brinell hardness number.

4. Results and discussion

4.1 Tensile Strength of Composites

The composite specimens are tested for tensile properties in universal testing machine and obtained tensile strength are shown in figure 4. It is found that the tensile strength of composite 4 is higher than other six composites. Composite 7 is strained less than the others, so it is more brittle but the composite 4 which is a hybrid composite is more ductile. From the tensile test results, it can be concluded that composite 4 has higher tensile strength than rest composites. Hence composite 7 should be use when brittleness is required.
4.2 Flexural Strength of Composites

The flexural strength is one of the important factors in NFRPCs and Fig. 5 shows the variations in the flexural strength of composites with the effect of wt% of filler content. It can be seen that flexural strength of specimen C7 is higher than that of rest specimens. From Fig. 5, it can be seen in graph that the flexural strength in case of 5% and 15% filler content composites decreases linearly but in case of 10% filler content composites increasing. The flexural break load of composite C7 is as high as compared with flexural break load of other composites. It was observed that the flexural strength values are increased with the increase in wt% of banana filler.

4.4 Hardness (BHN) of Composites

In the case of rice husk filler loading hardness are increases. In the case of chopped banana filler loading hardness increases (5wt% to 10wt %) but decrease when filler loading is 15wt% it may be due to improper bonding of matrix and reinforcement. The maximum hardness obtains at 10% chopped banana filler loading (C3)and minimum hardness obtains at 5wt% rice husk filler loading (C5) irrespective of fiber orientation, it is observed from the Figure 6.
4.3 Impact Strength of Composites

The loss of energy during impact is the energy absorbed by the specimen during impact. The values are furnished in figure 7. It is found that C6 absorb more energy than other composites. The reason for higher impact strength is due to the fibre arrangement on both sides of the composite. Hence it is difficult for cracks to propagate, when all the layers are of different types of fibre and fibre stacking sequence is lot more important [36]. Fig.7 shows the comparison between Energy absorbed by seven composites.

5. Conclusions

The experimental study on the effect of different natural filler loading on physical, water absorption, wear and mechanical behaviour of hybrid composites leads to the following conclusions:

1. The successful fabrications of a new class of polyester based hybrid composites reinforced with glass fibre and different natural fillers (chopped banana, rice husk) have been done. The present investigation revealed that filler loading significantly influences the different properties of composites.

2. In the case of chopped banana filler loading tensile strength are increases. In the case of rice husk filler loading tensile strength increases (5wt% to 10wt %) but decrease when filler loading is 15wt%. The maximum tensile strength obtains at 15wt% chopped banana filler loading and minimum tensile strength obtains at 15wt% rice husk filler loading.

3. In the case of rice husk filler loading flexural strength increases (5wt% to 10wt %) but decrease when filler loading is 15wt%. The maximum flexural strength obtains at 15wt% chopped banana filler loading and minimum flexural strength obtains at 15wt% rice husk filler loading irrespective of fiber orientation.
4. In the case of chopped banana filler impact strength are increases. In the case of rice husk filler loading irrespective of fiber orientation impact strength increases (5wt% to 10wt%) but decrease when filler loading is 15wt%. The maximum impact strength obtains at 10wt% rice husk filler loading. The minimum impact strength obtains without filler loading.

5. In the case of rice husk filler loading hardness are increases. In the case of chopped banana filler loading hardness increases (5wt% to 10wt %) but decrease when filler loading is 15 wt%. The maximum hardness obtains at 10% chopped banana filler loading (C3) and minimum hardness obtains at 5wt% rice husk filler loading (C5) irrespective of fiber orientation.

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