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A Comparative Study of Physical and Mechanical Properties of Glass Fiber /Polyester Composite Materials 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 composites alternative to the use of 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 satisfactory mechanical properties. For a composite material, its mechanical, physical, wear and water absorption behaviour depends on many factors such as fiber content, orientation, types, length etc. Attempts have been made in this research work to study the effect of different natural fillers loading on the physical, mechanical, wear and water absorption behaviour of glass fiber/natural fillers reinforced polyester based hybrid composites. A hybrid composite is a combination of two or more different types of fibre in which one type of fibre balance the deficiency of another fibre or filler. Composites of various compositions with four different fillers loading (5 wt%, 10wt% and 15wt%) and glass fiber loading is constant (20 wt%) with constant matrix material (polyester resin) are fabricated using simple hand lay-up technique. Different natural fillers which used in present research work are chopped banana, rice husk, wheat straw, and wood powder fillers. It has been observed that there is a significant effect of filler loading on the performance of glass fiber/natural fillers reinforced polyester based hybrid composites. TOPSIS a multi-criteria decision making approach is also used to select the best alternative from a set of alternatives.**

Keywords- **Glass Fiber /Polyester Composite Materials ,Natural Fillers, TOPSIS.**

I. INTRODUCTION

Composite materials have been used by men sinceancient ageand yarn is probably oneof the greatest developments of mankind which enabled him to surviveany climateareaand toexplore the surfaceof theearth hence flexible fabrics madeof cotton, flax and jute wereexcellent compared toanimal skins. Ageafter age useof thecomposite materials with natural resources increased continuously in the form of straw reinforced walls, composite bows and cross bows, chariots madeof thecombination of layers of wood, bones and horns.

In today's modern age growing population and product requirement has triggered theissueof low cost manufacturing material which should possess mechanical properties good enough to meet the standards and which can also be renewable resource to meet the requirement easily anywherein the world. Composite materials with natural fiber haveattracted attentions of many researchers worldwide becauseof their low cost and easeof manufacturing.In these days polymer composite materials areextensively used in engineering applications due to their excellent specificphysical and chemical properties. They also find applications in fields where high resistance to wear, abrasion and erosion is required (mining, automobile, domesticequipment, aerospace, marine, sports etc.).Automobileindustries are showing the highest interest towards natural fiber composites and alsoin many European countries they havealready decided to use mostly bio-degradableand ecofriendly materials for the manufacturing of theautomobilecomponents especially in cars.

JérômePORA [5] gives theapplications of composite materials and technologies on airbus A380, reliability of cost prediction arealso highlighted. Compositecentral wing box, representing a weight saving of up tooneand a half tones compared to the most advanced aluminium alloys. The upper deck floor beams and the rear pressure bulkhead will be madeof CFRP (Carbon Fiber Reinforced Plastic). Commercial aircraft manufacturers havecontinuously increased compositeapplications for primary structures. On A380 advanced manufacturing technologies such as Automated Fiber Placement, Automated Tape Laying, Resin Film Infusion and Resin

Transfer Moulding areexpected tocontribute tocost reductions in composite manufacture.Nikhil V Nayak [6] gives a review of some of these developments with a discussion of the problems with the present generation composites and prospects for further developments. Nayak finally conclude that Composite materials offer high fatigue and corrosion resistance and have high strength to weight ratio. So they are best suited for various aerospace applications.

Sukhwinder Singh Jolly [7] Study on theapplication of composites materials and find wideapplications in aircraft and rocket components due to their excellent strength to weight ratio; a few of them arepipes, sporting goods and military helmets, military and commercial aircrafts and rocket components, helicopter blades, automotive bodies, leaf spring, drive shafts, ladders, pressure vessels, boat hulls and various other structures etc. For better mechanical properties, physical properties and thermal properties, we usecomposite material.David Roylance [8]introduces basicconcepts of stiffness and strength underlying the mechanics of fiber-reinforced advanced composite materials. Many composites used today areat the leading edgeof materials technology, with performanceand costs appropriate to ultra demanding applications such as spacecraft.

G.V.Mahajan et al [9] presents design method and vibrational analysis of composite propeller shafts. In this paper, the aim is to replace a metallic drive shaft by a two-piece composite drive shaft. Author concluded, composites have attractive mechanical and physical properties that are now being utilized in automotive industry and aerospace on a grand scale world-wide. New fibers, polymers, and processing techniques for all classes of composites are constantly being developed. Research is also ongoing to improve repair techniques, recyclability, and the bonding between fibers and matrix materials.

Gururaja M N et al [10] gives review on hybrid composites that provide combination of properties such as tensile modulus, compressive strength and impact strength which cannot be realized in composite materials. Hybrid composites have been established as highly efficient, high performance structural materials and their use is increasing rapidly. Hybrid composites are usually used when a combination of properties of different types of fibers have to be achieved, or when longitudinal as well as lateral mechanical performances are required.

Xue Liet al [11] studies on poor compatibility between fiber and matrix and the relative high moisture sorption. Therefore, chemical treatments areconsidered in modifying the fiber surfaceproperties. Thechemical treatment of fiber aimed at improving theadhesion between the fiber surfaceand thepolymer matrix may not only modify the fiber surface but alsoincrease fiber strength. Water absorption of composites is reduced and their mechanical properties areimproved.

II. OBJECTIVE OF THE PRESENT RESEARCH WORK

Keeping in view theabove mentioned knowledge gaps, the following objectives werechosen for thepresent research project work.

- Fabrication of a new class of polyester based hybrid composites reinforced with randomly oriented glass fibers, banana fibers, wheat straw, rice husk and wood powder.
- Evaluation of theoretical density, experimental density and volume fraction of voids.
- Evaluation of mechanical properties (such as Tensile strength, flexural strength and Impact strength) of thecomposites.
- To study theinfluenceof different fillers loading on hardness, wear behaviour and water absorption behaviorof composites.
- To select the best alternative from a set of alternative materials using TOPSIS method.

III. MATERIALS AND METHODS

In this chapter describes the material required, fabrication method and the experimental procedures followed for their characterization. It presents details of the characterization and tests conducted on composites specimens. Materials used in present research work are:

- Polyester Resin
- Hardener (MEKP)
- Accelerator
- E-Glass fiber
- Banana fiber
- Rice husk
- Wheat straw
- Wood powder

1. MATERIALS

1.1 Matrix Material

Due to the several advantages over other thermoset polymers as mentioned above, unsaturated polyester is chosen as the matrix material for the research work. This resin belongs to “polystyrene family” this resin supplied from Amtech Esters Pvt. Ltd. New Delhi, India. The properties of polyester resin are listed in the table 3.1.

2. Fiber Material

Reinforcement provides strength and rigidity, helping to support structural load. E-glass fiber chopped strand mat is taken as reinforcement in thepolymer matrix to fabricatecomposites. E-Glass fiber chopped strand mat was collected from AMTECH ESTERS PVT. LTD. NEW DELHI. Process density and modulus of E-glass fiber is

2.58 gm/cm3and 72 GPa. Fiberglass is a strong lightweight material and is used for many products.

Table I: properties of polyester resin.

S. No.	Properties	Values
1	Appearance	Pale yellowish clear liquid
2	Viscosity at 25°C	500-600 cps
3	Volatilecontent	34-36%
4	Acid value	23-27 mg KOH/gm
5	Density at 25^0C	1.15-1.21 gm/cc
6	Cross linking mixture	1.5% catalyst and 1.5% accelerator
7	Gel timeat 25^0C	15-25 min.

Although it is not as strong and stiff as composites based on carbon fiber, it is less brittle, and its raw materials are much cheaper. Its bulk strength and weight arealso better than many metals, and it can be more readily molded intocomplex shapes. Applications of fiberglass includeaircraft, boats, automobiles, bath tubs and enclosures, swimming pools, hot tubs, septic tanks, water tanks, roofing, pipes, cladding, casts, surfboards, and external door skins.Chemical compositions: 55% silicon dioxide, 20% calcium oxideand 14% aluminum oxide, 10% boron oxide, 0-1% sodium and potassium oxide, 0-6% magnesium oxide.The strength, stiffness, hardness of glass fiber is better than most of other available material.

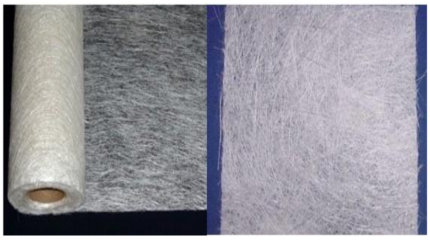

Fig.1.E- glass fiber chopped strand mat.

3. Filler Material

3.1 Banana Chopped Filler

Composite material of banana fiber used in buildings boards and fire resistance boards. During the research it was found that paper madeout of this fiber has long lifeof over 100 years as it is strongest of the long fibers over found other natural fibers, which can be folded 3,000 times.

Fig.2.Bananachopped fillers.

3.2 Rice Husk Filler

Worldwideproduction of rice husk is about 120 million tons per year. It is highly resistant to moisturepenetration and fungal decomposition. Husk therefore makes a good insulation material. Rice husk has low bulk density of only 70-110 kg/m³, 145 kg/m³ when vibrated or 180kg/m³ in form of brickets or pellets.. Density of rice husk fiber is 2.25 gm/cc. Becauseof the high silicacontents rice husk is very abrasiveand wears conveying elements very quickly.Rice husk contains 20% ash, 22% lignin, 38% cellulose, 18% pentosans and 2% moisture. A typical composition of ash is 95% SiO2, 2% K2O, 1% CaO, P2O5, Na2O3, Fe2O3& MgO. The silicain rice husk originally is present in amorphous form but after carburizing it becomes crystalline.

Fig. 2 Wheat straw.

3.3 Wheat Straw

Wheat straw is the leftover canes after the wheat grains are harvested and is treated mostly as waste. Chemical properties including cellulose (49.78%), lignin (19.64%), ash (5.28%) and extractives(4.93%) contents were determined. Fiber length, diameter, lumen width and cell wall thickness were 1140, 19.32,10.54 and 4.39 µm, respectively. The moisturecontents of wheat straws werein the rangeof 5.02-7.79%. The majority (56.87-93.36%) of the wheat straws particles were less than 0.85 mm and theaverageparticle sizes werein the rangeof 0.38-0.69 mm.

Fig.4. Wheat straw filler.

3.4 Wood Powder Filler

Wood powder/flour is finely pulverized wood that has aconsistency fairly equal to sand or sawdust, but can vary considerably, with particles ranging in size from a finepowder to roughly the sizeof a grain of rice. Most wood flour manufacturers areable tocreate batches of wood flour that have the sameconsistency throughout. All high quality wood flour is made from hardwoods becauseof its durability and strength. Wood flour is commonly used as filler in thermosetting resins such as bakelite, and in linoleum floor coverings. Wood flour is also the main ingredient in wood/plasticcomposite building products such as decks and roofs.

Fig.5. Wood powder filler.

4.Composite Fabrication

The fabrications of composite slab arecarried out by conventional hand layup technique. E-glass chopped strand mat are used as reinforcement and polyester resin is taken as matrix material with natural fillers (banana fiber, wheat straw, rice husk, wood powder). The low temperaturecuring polyester resin, hardener and accelerator are mixed in a ratio of 100:1.5:1.5 by weight percentage.Aplywood mould having dimension of (310 ×210× 20) mm^{3}is used for composite fabrication.

The natural fillers are mixed with polyester resin by the simple stirring and the mixtureis poured into various moulds conforming to the requirements of various testing conditions and characterization standards. Thecomposite samples of different compositions with different weight percentageof fillers areprepared. Weight percentageof glass fiber and polyester resin are fixed. A releasing agent is used for facilitateeasy removal of thecomposite 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 aroom temperature for 24 h at a constant loadof 25-30kg. After curing the specimens of suitable dimensions arecut for mechanical test as ASTM standard. Thecomposition and designation of thecomposites prepared for this study are listed in Table 2.

Table II: Designation of Composites.

S. N.	Composites	Compositions
1.	C1	Glass fiber(20%) + Polyester
2.	C2	Glass fiber(20%) +Banana chopped filler (5%) +Polyester
3.	C3	Glass fiber(20%) +Banana chopped filler (10%) +Polyester resin
4.	C4	Glass fiber(20%) +Bananachopped filler (15%) +Polyester resin
5.	C5	Glass fiber(20%) +Rice husk filler (5%) +Polyester resin
6.	C6	Glass fiber(20%) +Rice husk filler (10%) +Polyester resin
7.	C7	Glass fiber(20%) +Rice husk filler (15%) +Polyester resin
8.	C8	Glass fiber(20%) +Wheat straw filler (5%) +Polyester resin
9.	C9	Glass fiber(20%) +Wheat straw filler (10%) +Polyester resin
10.	C10	Glass fiber(20%) +Wheat straw filler (15%) +Polyester resin
11.	C11	Glass fiber(20%) +Wood powder filler (5%) +Polyester resin
12.	C12	Glass fiber(20%) +Wood powder filler (10%) +Polyester resin
13.	C13	Glass fiber(20%) +Wood powder(15%) +Polyester resin

5. Fabrication Method (Hand Lay-Up Method)

Thereare numerous methods for fabricating compositecomponents. Bag moulding process, pultrusion, filament winding, dough moulding compounds, prepregs, sheet moulding compounds, resin transfer moulding etcare the methods for fabricating compositecomponentThe most basic fabrication method for thermoset composites is hand layup. Hand lay-upis the simplest method of fabricating.

The tooling and equipment is low cost and design changes can be readily made. This method is good for low to medium volumeparts. Hand lay-up gives a finished surfaceon one sideof theproduct only (the mould face). This is the most labour intensive method of fabricating. Skilled fabricators ensureconsistent quality. Hand lay-upis alsocalled open moulding or contact moulding. Glass or other reinforcing mat or woven fabricor roving is positioned manually in theopen mold, and resin is poured, brushed, or sprayed over and into the glass plies. Entrapped air is removed manually with squeegees or rollers tocomplete the laminates structure. Room temperaturecuring polyesters and epoxies are the most commonly used matrix resins.

6. Physical And Mechanical Tests

6.1 Density

The theoretical density of composite materials can beobtained as per theequations given by [54].

.
$$\rho_{ct} = \frac{1}{\left(\frac{W_f}{\rho_f}\right) + \left(\frac{W_m}{\rho_m}\right)}$$
(1)

Where, *W* and *ρ* represent the weight fraction and density respectively. ctis the theoretical density of thecomposite. The suffix f, m and ct stand for the fiber, matrix and thecomposite materials respectively the suffix p' indicates theparticulate filler materials.

Theexperimental density of thecomposite however can be determined experimentally by simple water immersion techniques.

$$\rho_{exp} = \frac{m}{\Delta h} \quad (2)$$

Where,
ρ_{exp}=experimental density of specimen (g/cm^3)
m = mass of specimen (g)
Δh = changein height of water level
The volume fraction of voids (V*v*) in thecompositeis determined by using the following equation.

$$V_v = \frac{\rho_{ct} - \rho_{ce}}{\rho_{ct}}$$
(3)

6.2 Tensile strength
The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. Thecommonly used specimen for tensile test is the dog-bone type. During the test a uniaxial load is applied through both theends of the specimen. The dimension of specimen is (130x12) mm. Typical points of interest when testing a material include: ultimate tensile strength (UTS) or peak stress. The tensile test is performed in the HEICO universal testing machine (UTM) and results areanalyzed tocalculate the tensile strength of composite samples. A uniaxial load was applied through theend of the specimen. The test recommends that the length of the test section should be 120 mm specimens with fibers parallel to the loading direction should be 11.5 mm wide. The test is repeated three times on each composite typeand the mean valueis considered.

$$TS = \frac{W}{bt}$$
(4)


Fig. 6.Tensile test specimen.


Fig.7. Experimental set upand loading arrangement for the specimens for tensile test.

7. Izod Impact test
As per using an impact tester theimpact tests are doneon thecomposite samples. Thependulum impact testing machine determines the notch impact strength of the material by devastating the V-notched sample with apendulum hammer, calculating theimpact strength. The standard sample sizeis 64 × 10 × 10 mm and the depth of the notch is (t/3=3.33 mm) 6.66 mm of the notch. The scaleof the machineis 1division=2 joule.


Fig .8. Izod impact testing machine.

Izod impact test as per the following equation [53]. Units Joules/mm^2.

$$IS = \frac{EI}{A}$$
(6)

Where,
EI= Impact energy in joules recorded on the scale
A= Area of the specimen

8. Dry Sand Abrasion Test

Theabrasion testing of composite specimens is performed on a standard abrasion test rig (supplied by DUCOM) as per ASTM G65 standard. Thepictorial and schematic diagram of abrasion test rig and specimens used in abrasion test are shown in **figure3.5.** The surfaceof the specimens was cleaned with a soft paper soaked in acetone before the test. The specimen weight was recorded using a digital electronic balance (0.1 mg accuracy) beforeit was mounted in the specimen holder**.** The difference between initial and final weight of the specimen was a measureof wear loss.

Thecomposite specimen of size (76mm x 23 mm) is pressed against a rotating wheel with achlorobutyl rubber tyreof specified hardness. Theabrasive was fed at thecontacting between the rotating rubber wheels and test specimen and the rateof feeding theabrasive was 365 g/min. A series of test conducted for constant time 20 min under different normal loadings 1.5 kg with test speed of 1.765 m/s. Specimen cut from thecompositeplates for abrasion test are shown in **figure 3.6.**The material losses from thecomposite surfaceare measured by using precision electronic balanceand then find the specific wear rate by using following equation.

$$W_S = \frac{\Delta m}{\rho l f_n}$$

(8)

Where,

W_s= specific wear rate (mm^3/N-m)

ρ =density of specimen (g/cm^3)

l = abrading distance (m)

f_n= normal load (N)

Fig.9.Dry sand abrasion test set up.

IV. RESULTS & DISCUSSION

1.Physical Characteristics Of Composites

1.1 Effect of fiber content density of composites- The experimental density can beeasily determined by using Archimedes principle. Density of acomposite depends on the relativeproportion of matrix and reinforcing materials and this is oneof the factors determining theproperties of thecomposites. The void content is thecause for the difference between the value true densities and theoretically calculated one. The knowledgeof void content is desirable for estimation of the quality of thecomposites. It is understandable good composite should have favorable voids.

And show the variation of theoretical, experimental density and void fraction Vs fiber loading filler and without filler glass fiber reinforce composite in figure and compare of the table 4.1 with 4.2 and table 4.1 with table 4.3.And the physicalproperties measured in the present work are well compared with various earlier investigators [56]. And show the variation of theoretical, experimental density and void fraction Vs fiber loading filler and without filler glass fiber reinforce composite in fig. 4.3, 4.6, 4.9.

The present investigation reveals that thepresenceof without mustard cakepowder (filler) has varied effect on the glass fiber and bamboo fiber reinforced polymer composites in term of mechanical properties as seen in Table 4.1. The density increases with increaseof wt % of glass fiber and bamboo fiber reinforced polymer composites. The density of neat polyester resin in this study is 1.37 g/cm^3 which increases to 1.473 g/cm^3 (with a void fraction of 5.52 %) with the reinforcement of 30 wt % of glass fiber in it.

Table III: Theoretical and Experimental densities of composite specimens along with void fractions in bamboo/glass fiber reinforcement.

S.N.	Composites	Theoretical Density (gm/cm^3)	Experimental density (gm/cm^3)	Volume fraction of voids (%)
1	PBG-1	1.560	1.473	5.52
2	PBG-2	1.618	1.484	7.79
3	PBG-3	1.660	1.512	8.91

when the glass fiber and bamboo fiber reinforced polymer is filled with micro-sized mustard cakeparticles, the density of resulting hybrid composites is increases to 1.466 g/cm^3 (with a void fraction of 7.03 %). 1.459 g/cm^3 (void fraction of 9.65 %) and 1.471 g/cm^3 (void fraction of 10.52 %) with the reinforcement of 50 wt % , 60 wt% and 70 wt% of glass fiber and bamboo fiber, but these different wt % of glass fiber and bamboo fiber reinforced polymer is filled with same wt% of filler (mustard cakepowder), the density of hybrid composites is increase to 1.635 g/cm^3 (void fraction of 4.04 %) and 1.692 g/cm^3 (void fraction of 7.15 %). Order of theoretical density, experimental density and void fraction of different specimens of composite.

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Table IV: Theoretical and Experimental densities of composite specimens along with void fractions in particle (pine needle) bamboo/glass reinforcement.

S.N.	Composites	Theoretical Density (gm/cm^3)	Experimental density (gm/cm^3)	Volume fraction of voids (%)
1	PBGPN-1	1.583	1.479	6.5
2	PBGPN-2	1.672	1.506	9.90
3	PBGPN-3	1.705	1.526	10.40

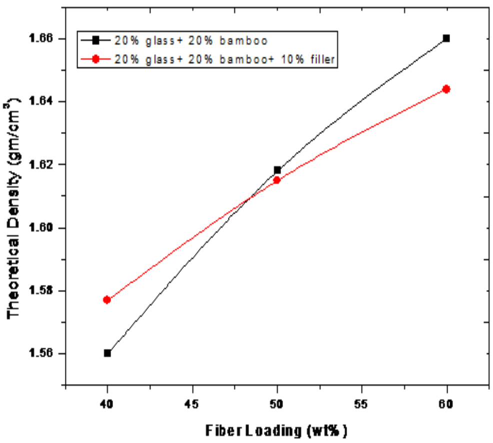

Fig.9. Variation of theoretical density Vs fiber loading with fillerand without filler glass/bamboo reinforcement.

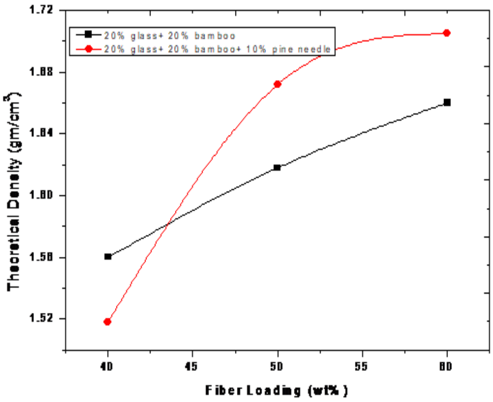

Fig.11. Variation of theoretical density Vs fiber loading with pine needleand without pine needle glass/bamboo reinforcement.

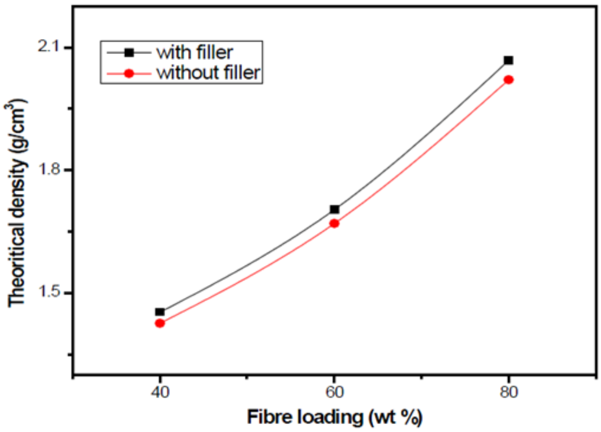

Fig.12. Variation of theoretical density Vs fiber loading with fillerand without filler glass fiber reinforcement [56].

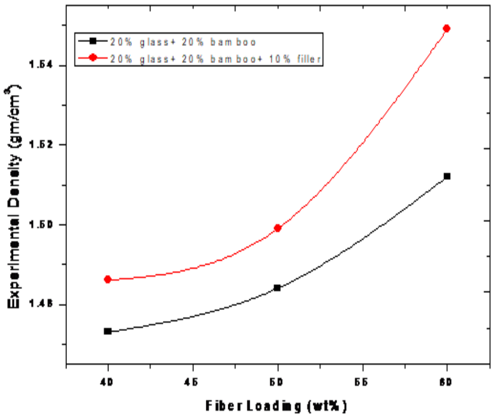

Fig.13.Variation of experimental density Vs fiber loading with fillerand without filler glass/bamboo reinforcement.

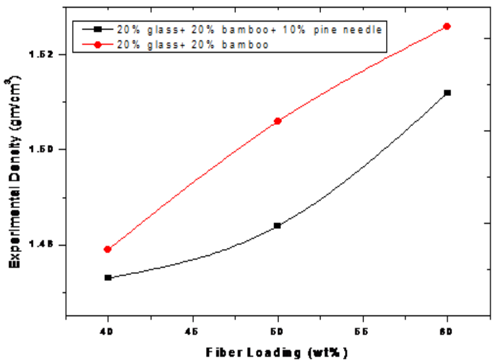

Fig.14. Variation of experimental density Vs fiber loading with pine needleand without pine needle glass/bamboo reinforcement.

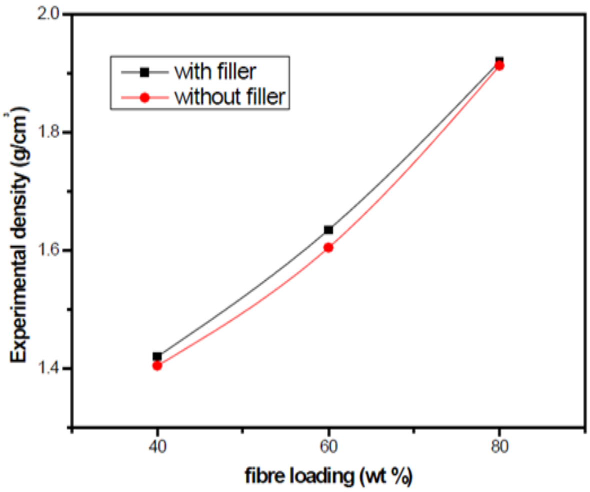

Fig.15.Variation of experimental density Vs fiber loading with filler and without filler glass fiber reinforcement [56].

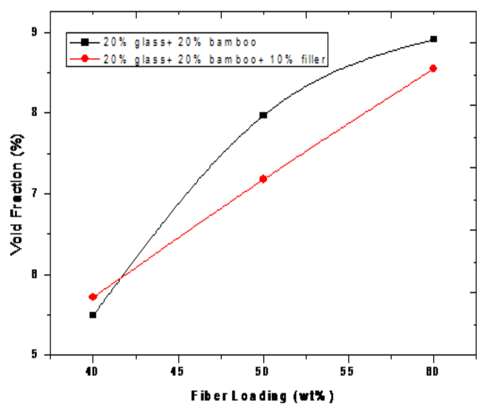

Fig.16. Variation of void fraction Vs fiber loading with fillerand without filler glass/bamboo reinforcement.

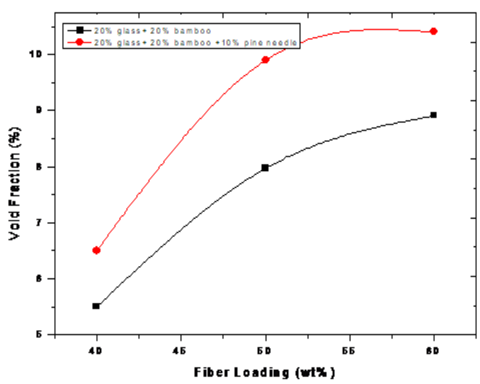

Fig.17. Variation of void fraction Vs fiber loading with pine needleand without pine needle glass/bamboo reinforcement.

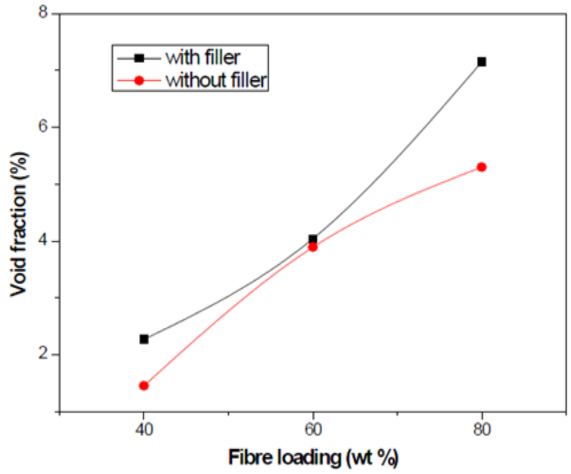

Fig.18. Variation of void fraction Vs fiber loading with fillerand without filler glass fiber Reinforcement [56].

Figure 9 to figure 18 gives the variation of experimental density, theoretical density and void fraction of thecomposites. The theoretical density, experimental density and void fraction of new material increases with increases of wt % of fiber in compositeand the theoretical and experimental density of filler based specimen are high and low as compared to without filled specimens on same fiber loading. the theoretical and experimental density of particle based specimen are no higher as compared to without filled specimens on same fiber loading This may be due topresent of higher air content with addition of mustard cakepowder filler in epoxy resin the volume fraction of void is increased.

1. Mechanical Characteristics of Composites

The mechanical properties of the glass fiber and bamboo fiber reinforced with filler (mustard cake) and particle (pine needle) polymer composites with different fiber loading under this investigation arepresented in Table 4.4, 4.5and 4.6. It is evident from the Table 4.4 that at 40, 50 and 60 wt% of fiber loading thecomposites show better mechanical properties as compared toothers.

Table V: Mechanical properties of the bamboo/glass fiber reinforced composites

Composites	Tensile strength (MPa)	Inter Laminar Shear Strength (Mpa)	Impact strength (J)
PBG-1	26.395	21.68	4.0625
PBG-2	29.864	25.26	3.7812
PBG-3	34.943	25.99	4.3120

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Table VI: Mechanical properties of filler based bamboo/glass fiber reinforced composite

Composites	Tensile strength (MPa)	Inter Laminar Shear Strength (Mpa)	Impact strength (J)
PBGF-1	35.091	26.24	4.375
PBGF-2	40.689	27.79	4.6870
PBGF-3	41.096	28.24	4.2187

Table VII: Mechanical properties of pine needle particle based bamboo/glass fiber composites

Composites	Tensile strength (MPa)	Inter Laminar Shear Strength (Mpa)	Impact strength (J)
PBGPN-1	29.447	23.45	4.0312
PBGPN-2	33.697	25.88	4.4687
PBGPN-3	35.298	26.75	4.2812

2. Effect of Fiber Loading on Tensile Strength of Composites

The tensileproperties of the glass fiber and bamboo fiber reinforced hybrid composites increase up to26.395to 34.943MPa with different fiber loading under this investigation are presented in Table 4.4. It is evident from the Table 4.4 that at 40, 50, 60 wt% fiber loading thecomposites. The tensileproperties of the glass fiber and bamboo fiber with filler (mustard cake powder) reinforced based hybrid composites increase up to35.091 to41.096 MPawith different fiber loading under this investigation arepresented in table 4.5. It is evident from the Table 4.5 that at 40, 50, 60 wt% fiber loading thecomposites.

The tensileproperties of the glass fiber and bamboo fiber with particle (Pine Needle) reinforced hybrid composites increase up to 29.447 to 35.298 MPa with different fiber loading under this investigation arepresented in Table 4.6. It is evident from the Table 4.6 that at 50, 60, 70 wt% fiber loading thecomposites. The tensileproperties measured in the present work are well compared with various earlier investigators [56]. And show the variation tensile strength Vs fiber loading filler and without filler glass fiber reinforce composite in fig.21.The variation of tensile strength of both filler (mustard cake powder) and pine needle particle basedcomposites with different fiber loading under this investigation is presented in figure 19, 20 and 21.

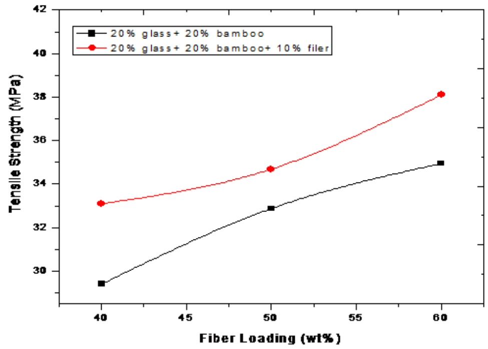

Fig.19.Variation of tensile strength Vs fiber loading with filler and without filler glass/bamboo reinforcement.

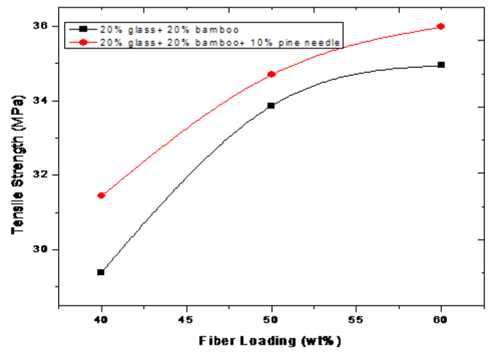

Fig.20.Variation of tensile strength Vs fiber loading with pine needleand without pine needle glass/bamboo reinforcement.

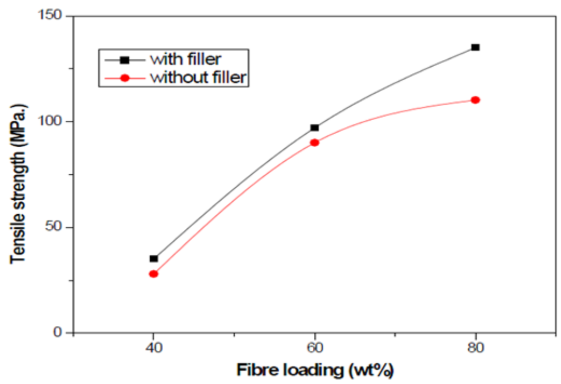

Fig.21.Variation of tensile strength Vs fiber loading with fillerand without filler glass fiber reinforcement [56].

3. Effect of Fiber Loading on Inter Laminar Shear Strength of Composites

The stress between theconsecutive laminaof layered compositeis called inter laminar shear stress. The result on inter laminar shear strength of the glass and bamboo fiber composite without fillers or particles arepresented in table 4.4, 4.5and 4.6. In thepresent work short beam shear test is carried out on thecomposites with different fiber loading to determine theILSS (inter laminar shear strength). The variations of ILSS of bidirectional glass and bamboo fiber composite without fillers or particles composite under this investigation are shown in figure 4.13, 4.14 and 4.15. TheILSS of composites is gradually increases with increaseof wt % of bidirectional glass fiber and bamboo fiber. The inter laminar shear strengthproperties measured in the present work are well compared with various earlier investigators [56] and show the variation inter laminar shear strength Vs fiber loading filler and without filler glass fiber reinforce composite.

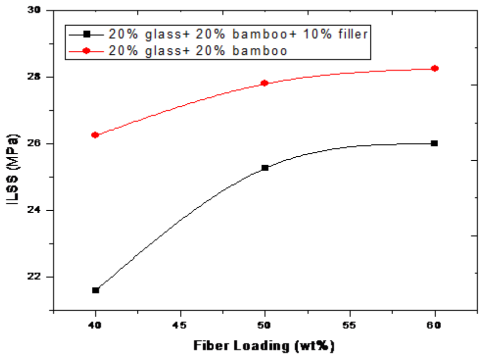

Fig.22. Variation of inter laminar shear strength Vs fiber loading with filler and without filler glass/bamboo reinforcement.

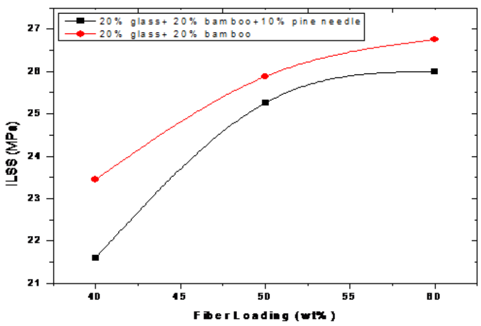

Fig.23. 4Variation of inter laminar shear strength Vs fiber loading with pine needleand without pine needle glass/bamboo reinforcement.

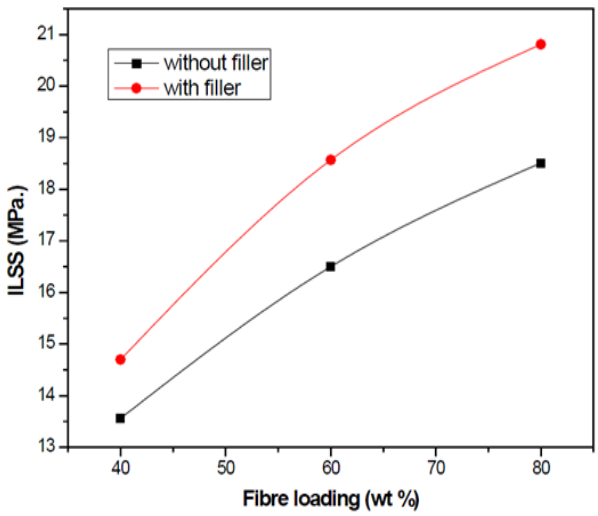

Fig.24. Variation of inter laminar shear strength Vs fiber loading with fillerand without filler glass fiberreinforcement[56].

Effect of Filler Loading on Impact Strength of the Composites. As seen from the Figure 4.16, theeffect of filler (mustard cake) or particle (pine needle) content has least effect on theimpact strength of thecomposites by theaddition of filler or particlecontents. However, theimpact strength starts decreasing up to 10wt% filler and 10% pine needlecontent and on further increasein filler content and particlecontent theimpact strength goes on increasing but comparatively lesser than without filler and particleof thecomposite. As impact strength is theability of a material to resist the fracture under stress applied at high speed. Theimpact properties of composite materials are directly related toits overall toughness. Composite fracture toughness is affected by inter-facial strength parameters.

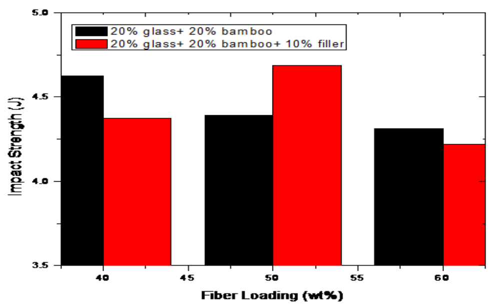

Fig.25. Variation of impact strength Vs fiber loading with filler and without filler glass/bamboo reinforcement.

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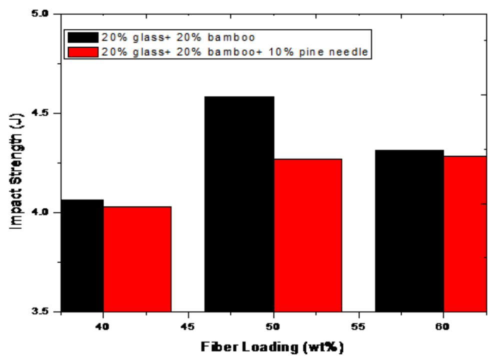

Fig.26. Variation of impact strength Vs fiber loading with filler and without filler glass/bamboo reinforcement.

According to thecomparison chart it can be seen easily that glass/ bamboo fiber is having maximum impact strength even from filler and pine needle particle based hybrid composites specimens. If natural bamboo/glass reinforcement specimen is observed, it is also having higher strength compare to hybrid composite specimen.

2. Study of Dry Sand Abrasion Wear

Each standard test was conducted for 14063.68 m of sliding distanceand 2.39 m/s of sliding velocity. **Fig 4.18** shows the variation of specific wear rate with normal load under steady stateconditions for bidirectional E-glass fiber and bamboo fiber reinforced polymercomposites with filler and without filler. It is observed that at load (14.7N) and (40, 50 and 60wt %) of glass fiber and bamboo fiber in composites (with filler and without filler) exhibit highest wear rate.

PBG-1 composite sampleexhibit highest wear rate becauseat this loading thereare less fibers to support the polymer matrix and thereforeabrasiveparticlecreate large depth grooves and serves as cutting modeof abrasive wear. PBG-3 composite sampleexhibits lower wear rateas compared toother composites without filler becauseat high fiber loading thereis comparatively good adhesion between the fiber and matrix moreover with simultaneous occurrenceof different orientation of the fiber surface seems to lead toa synergetic behavior that is wear protectiveperformance.

Table VIII: Specific Wear RateBamboo/Glass Fiber Composites (under dry sand abrasion)

Sample No.	Initial Wt. of Work Piece (Gm)	Final Wt. of Work Piece (Gm)	Loss of Wt. (Gm)	Abrading Distance (M)	Counter	Wheel Speed (RPM)	Loa Applied (N)	Specific Wear
PBG-1	22.108	21.811	0.297	14063.68	150	2000	14.7	9.207
PBG-2	20.391	20.185	0.206	14063.68	150	2000	14.7	6.158
PBG-3	22.503	22.304	0.199	14063.68	150	2000	14.7	5.798

Table IX: Specific wear rateof filler based bamboo/glass fiber composites (under dry sand abrasion)

Sample No.	Initial Wt. of Work Piece (Gm)	Final Wt. of Work Piece (Gm)	Loss of Wt. (Gm)	Abrading Distance	Counter	Wheel Speed (RPM)	Load Applied (N)	Specific Wear Rate (M^3/Nm) 10-
PBGF-1	22.019	21.704	0.315	14063.68	150	2000	14.7	9.661
PBGF-2	22.198	22.900	0.298	14063.6 8	150	2000	14.7	8.925
PBGF-3	21.381	21.132	0.249	14063.68	150	2000	14.7	7.326

Table X: Specific wear rateof pine needleparticle based bamboo/glass fiber composites (under dry sand abrasion)

Sample N	Initial Wt. of Work Piece	Final Wt. of Work	Loss of Wt. (Gm)	Abrading Distance	Counter	Wheel Speed (RPM)	Load Applied	Specific Wear
PBGPN-1	22.225	21.864	0.361	14063.68	150	2000	14.7	9.813

PBGPN-2	22.380	22.152	0.228	14063.68	150	2000	14.7
PBGPN-3	23.498	23.311	0.187	14063.68	150	2000	14.7

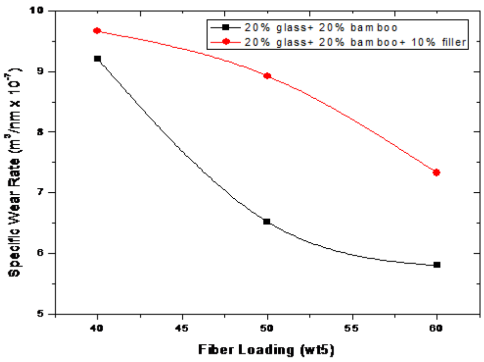

Fig.27.Variation of specific wear rate Vs fiber loading with filler and without filler glass/bamboo reinforcement.

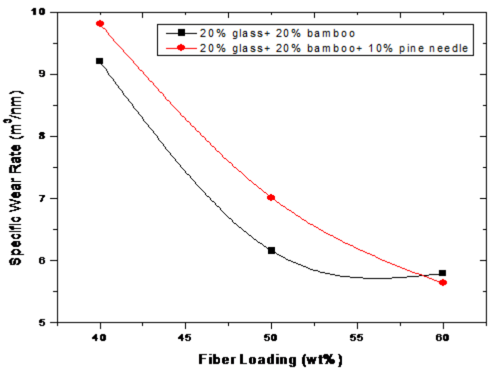

Fig .28.Variation of specific wear rate Vs fiber loading with pine needleand without pine needle glass/bamboo reinforcement.

V. CONCLUSION

The Glass fiber, Bamboo fiber, Pine needleand Filler (mustard cake powder) fiber was successfully fabricated hybrid natural fiber reinforced composite with the 40, 50 and 60% fiber loading.Theexperimental investigation on theeffect of fiber loading pine needle particle (10mm) and filler content on physical and mechanical behaviour of glass fiber and bamboo fiber reinforced polymer composites wereconducted. Physical properties such as theoretical density, experimental density and void fraction and mechanical properties such as tensile strength, inter laminar shear strength, impact strength, Brinell hardness and specific wear rate wereevaluated from various experiments. Theexperiments load us to the following conclusion obtained from this study.The bamboo/glass composites have three different fiber loading i.e. (20:20) wt%, (25:-25) wt%, (30-30) wt% (bamboo glass fiber loading) compare to the bamboo fiber, glass fiber, filler (mustered cake powder) and pine needle particlecomposites three different fiber loading i.e.

(20:20:10) wt%, (25:25:10) wt%, (30:30:10) wt% (bamboo , glass and filler or pine needle particle). The physical and mechanical property compared at each other. The physical properties like void fraction and density of glass fiber based epoxy hybrid composites have been studied. The density and void fraction of filled composites is increased as compared to unfilled composites. This may be due to present of high air content in the reinforcement.

It has been noticed that the mechanical properties of the composites such as tensile strength, inter laminar shear strength and impact strength of the composite also greatly influenced by the fiber loading and fillers, pine needle particles. The abrasive wear performance of glass/bamboo fiber composites improve with incorporation of particulate fillers and pine needle particle. Among the four weight percent of bamboo/glass fiber in the composites, 60 wt % bamboo/glass fiber mustard cake filled composites has shown maximum wear resistance.

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