Development and Characterization of Natural Hybrid Composite using Basalt and Bamboo Fibers

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Abstract - *With rapid changes in the environment the demands for technologies of the best suitable composite materials has begun. Materials having required characteristics along-side remaining non-pollutant are being researched and formulated to be put them in use. With the availability of natural fiber composites which share proportionate properties with that of manmade fibers are added together with a matrix to achieve best and good outputs. The hybrid composite materials are a blend of natural and synthetic fibers which are either in same proportion or varied with respect to a preferred ratio to have desired properties. This present work deals with the study mechanical properties of basalt fiber composites having bamboo fibers and E-glass fibers to which varying concentration of Silicon carbide (SiC) are added and reinforced with epoxy resin as the matrix. The overall mechanical properties of the composites showed improvement with the addition of silicon carbide in the matrix.*

***Key Words*: Bamboo fiber, Basalt fiber, Silicon Carbide**

1. INTRODUCTION

The word composite is derived from the word "compositus‟ which means mixing together. Composite materials refer to combining of two or more materials. They constitute of both matrix material and a reinforcing agent. The matrix usually binds the reinforcement stiffly thus creating a firm bonding with the different reinforcement thus forming a composite material. A composite consists of two or more materials of different nature to achieve a material of required property. The material formed after the combination of two materials will have much better and sophisticated characteristics than the constituent. Paliwal et.al.[2] Investigated about the composites fabricated from glass fibers with epoxy as a matrix material and calcium carbonate (CaCo3) as a particulate filler material which showed overall increase in their mechanical properties.

The reason is that the particulate fillers increase the loading capacity by increasing the bonding strength between the reinforcement and the matrix material. Potluri et.al.[3] used silicon carbide as a filler material with varying proportions in pineapple leaf fiber composites. The specimen with the higher percentage of silicon carbide showed higher strength, Young's modulus and shear modulus. Nguong et.al.[4] used silicon carbide as a filler material in natural fiber reinforced polymer composites. The results showed significant wear resistance because of the stronger bonds created with the inclusion of the filler material which behaved as a crack arrestor. Chisholm et.al.[8] In his research the carbon epoxy composites are subjected to testing one without any (SiC) filler and the other with (SiC) filler. The results confirm that the infusion of (SiC) brought about good thermal stability and also a good amount of strength (mechanical).

2 MATERIALS AND FABRICATION

The 300 mm x 300 mm x 4 mm composite was manufactured using the hand-layup method. The resin was coated with brush and roller and kept between the 350 mm x 350 mm pressing plates. A polyester film layer between the plate and the composite surface was provided for easy release and for smooth and uniform surface surfaces on the composites. Lapox L-12 (Epoxy) resin matrix is used with Hardener K-6 as the catalyst and SiC filler having mesh size of 220 has been added to five different percentages (0 wt. %, 10 wt. %, 20 wt. % and 30 wt. percent).

Alternative layers of basalt fabric and bamboo fabric are fabricated with epoxy resin mixed with SiC filler one above the other until the desired thickness is achieved. The composites were then left at room temperature for 24 hours to be solidified. Composites were then removed from the mold following the curing process.

2.1 Fabrication procedure followed


Fig - 1: Slab forming the mold


Fig - 2: Placing of Release Film


Fig - 3: Resin coated on release film


Fig - 4: First layer of reinforcement


Fig - 5: Squeezing of excess resin


Fig - 6: Curing Stage

3. MECHANICAL TESTING OF HYBRID COMPOSITE MATERIAL

The specimens are derived from the fabricated material and subjected to different mechanical testing processes to determine their performance under various loading conditions. The results are then analyzed and further the materials are engineered to improve the characteristics so that a better product can be achieved.

3.1 Tensile test

It is one of the most commonly used testing processes to evaluate the mechanical properties of the material. The tests help to evaluate the properties related to elasticity and strength. In a tensile testing process, a specimen is obtained according to a prescribed standard and loaded under uni-axial force applied at two ends until the matrix is fractured.

The testing carried out helps us to determine the elastic deformation and then the plastic deformation. The fracture of the specimen is the indication of the end in plastic deformation. The ductile materials have greater plasticity and have good strength compared to brittle materials whose plasticity is low. The testing process is carried out by constantly and gradually rising the applied load. The change in length of the test piece is noted. Hence a set of collective information is available to calculate the results.

3.2 Flexural test

The specimens used in the testing process are generally rectangular in geometry without any bond or notches. The flexural test helps us to determine the strength in brittle material because when the same material is gripped and loaded for testing would easily breakdown. Within the elastic range, a linear relation between a load and deflection can be noted. The failure first begins on a thin layer of the surface which initiates the cracking process and at-last leads to the specimen break point.

3.3 Impact test

The behavior of materials vary according to the loading conditions they are subjected in. a cyclic load may yield different results when compared with sudden loading or when it is loaded constantly. Hence the impact test helps us to know the behavior during sudden loading conditions.

Izod impact testing is an ASTM standard method of determining the impact resistance of materials. A pivoting arm is raised to a specific height (constant potential energy) and then released. The arm swings down hitting a notched sample, breaking the specimen. The energy absorbed by the sample is calculated from the height the arm swings to after hitting the sample. A notched sample is generally used to determine impact energy and notch sensitivity.

3.4 Hardness test

Hardness is the mechanical property of the material which helps it to resist the indentation. Hardness is one of the important parameters in the designing of a material. The process of measuring the hardness is by measuring the depth of the indentation mark left on the material when a load of known pressure is applied on it.

3.5 Specific gravity test

The density of a particular object is dependent on the phase it is in and the temperature. With density one can identify the material and also response when placed in fluid can be easily determined. If the density of the material is greater than the water it will sink. And when the density is less it will float. Water is the fluid generally used to determine the measurement.

The density ρ is obtained from

$$\rho = \frac{(0.995)a}{(a + w - b)}$$

Where,

a - Weight of the specimen in air

b – Total weight of the specimen and sinker (if used) in water

w – Weight of immersed sinker if used and partially immersed wire

4 RESULTS AND DISCUSSION

4.1 Tensile Test

Tensile tests are used to determine the material behavior under a tension. The process takes place by placing the specimen on the machine and pulled to the point of breaking. The results are used to determine the maximum load, ultimate tensile strength, poisons ratio and Young's modulus. The testing process requires the specimen to be prepared according to ASTM D-638 standards. The specimen is loaded on a computerized universal testing machine for higher accuracy. A maximum of 20KN can be applied for testing

Table-1: Tensile test result of natural and hybrid composite material

Materials	Maximum load (KN)	Ultimate Tensile Stress (Mpa)	Young's Modulus (Mpa)
Basalt+bamboo	8.12	110.20	5200.78
Basalt + bamboo + glass	9.00	122.58	5353.55
Basalt+bamboo+glass+10%(SiC)	10.78	131.18	5424.23
Basalt+bamboo+glass+20% (SiC)	11.40	141.94	5590.43
Basalt+bamboo+glass+30% (SiC)	11.67	146.56	5836

All the specimens were prepared as per the standards and the orientation is maintained at a constant 0º throughout for the fabrication process. For the first combination (Basalt + bamboo + glass) with 0% (SiC) the maximum load is 9.00 KN, with an ultimate tensile stress of 122.58Mpa with a Young's modulus of 5353.55 Mpa, the specimen (Basalt+bamboo+glass+10% (SiC)) the load is increased to 10.78 KN this is due to the process that added (SiC) creates a stronger bond between the matrix and reinforcement which increases the loading conditions, thus this effect can be seen with the ultimate tensile stress increasing to 131.18Mpa.

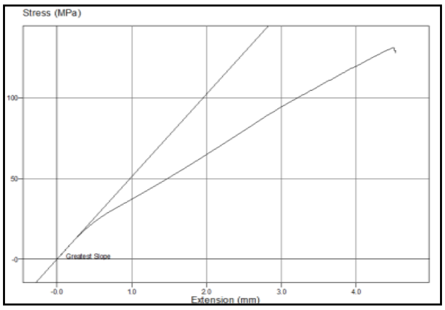


Fig – 7: Basalt + bamboo

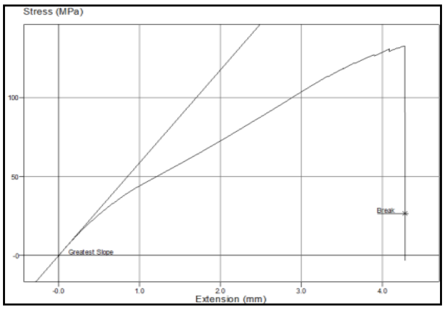
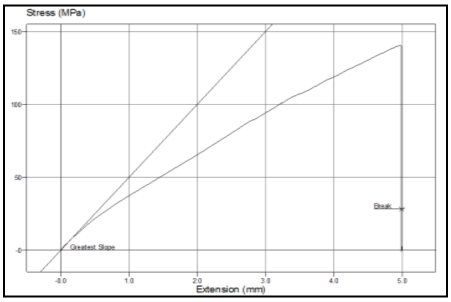


Fig – 8: Basalt + bamboo + glass



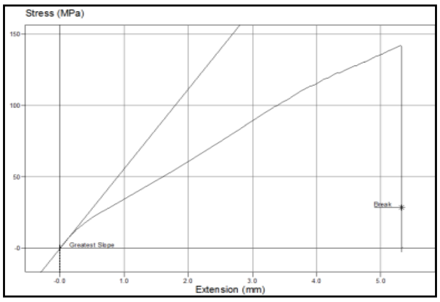


Fig – 9: Basalt + bamboo + glass + 10 % (SiC) **Fig – 10:** Basalt + bamboo + glass + 20 % (SiC)

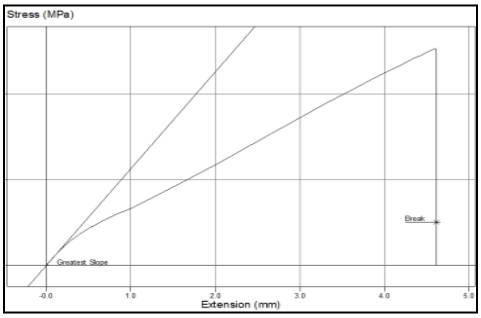


Fig – 11: Basalt + bamboo + glass + 30 % (SiC)

Fig (7-11) showing Extension vs. stress graphs of the tensile test specimen

Chart -1: Comparison of materials for ultimate tensile strength

When the concentration is increased by a large amount i.e. 30% the increase in strength has increased by a smaller value this is due to the fact that the infused particles start to form a lump and reduced interaction between polymer and particle results in lesser strength as compared with that of 10% and 20% (SiC) specimens. This is because polymer and particle interaction has more strength when compared with particle and particle interaction.

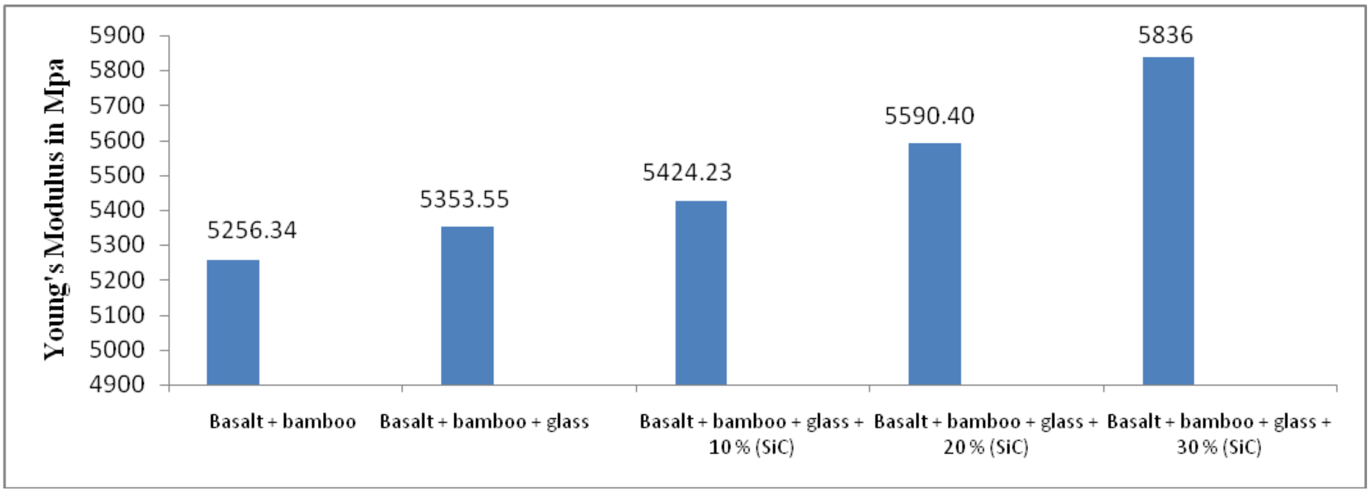


Chart -2: Comparison of Materials for Young's Modulus

4.2 Flexural test

The tests are used to determine the flexural strength of a material. The testing material is laid horizontally onto the two points of contact and then a force is applied on the top of the material through either one or two points of contact until the specimen fails.

Table 2: Flexural test results for natural and hybrid composite materials

Materials	Maximum load (KN)	Maximum bending stress at maximum load (Mpa)	Young's Modulus (Mpa)
Basalt+bamboo	539.41	213.698	10342.14
Basalt + bamboo + glass	550.50	240.74	10885.37
Basalt+bamboo+glass+10%(SiC)	830.41	302.25	11151.36
Basalt+bamboo+glass+20% (SiC)	872.88	340.58	11350.69
Basalt+bamboo+glass+30% (SiC)	898.80	351.56	11652.36

All the specimens being tested have a fixed orientation of 0°. For the specimen of (Basalt + bamboo + glass) the maximum bending stress is recorded at 240 Mpa with Young's modulus of 10885.37 Mpa for a maximum applied load of 550.50 KN. Now with the inclusion of 10% Silicon the maximum bending stress increases to 302.25 Mpa where as the young's modulus is 11151.36 Mpa and the maximum load for failure is 830.48 KN.

This is because the added (SiC) increases bonding capacity between the matrix and reinforcement thus increasing the overall flexural strength, Young's modulus and loading capacity. And when the (SiC) concentration is increased to 20% the maximum bending stress also increases to a value of 340.58 Mpa and Young's modulus to 11350.69 and the maximum load applied increases to 872.88 KN.

For the specimen with 30% (SiC) the load applied and maximum flexural strength increase but in a smaller value. This is because the bonding has already happened between the matrix and the reinforcement hence the remaining (SiC) particles just slightly increase the loading conditions and for the rest their performance is almost similar to that of the specimen with 20% (SiC). For the specimen combination of (Basalt + bamboo) without the E-glass fiber and (SiC) in the resin system the flexural strength, load applied and Young's modulus has the least values because the material can easily fail since it has no additional bonds which were present when (SiC) was added into the system.

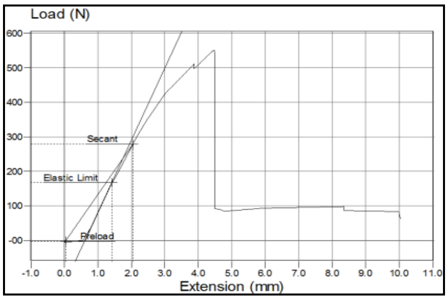


Fig – 12: Basalt + bamboo

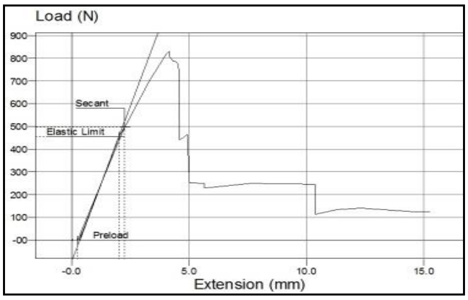


Fig - 13: Basalt + bamboo + glass

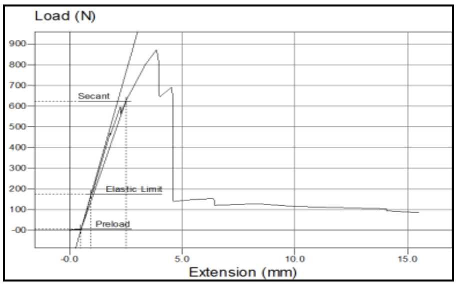


Fig - 14: Basalt + bamboo + glass + 10 % (SiC)

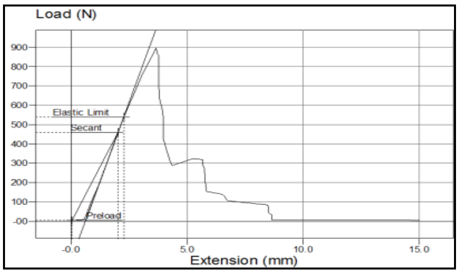


Fig - 15: Basalt + bamboo + glass + 20 % (SiC)

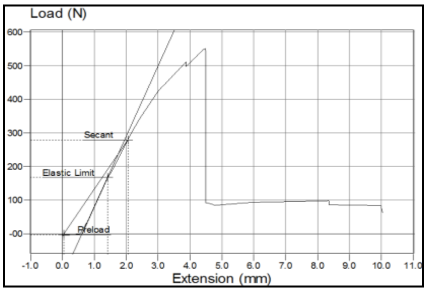


Fig - 16: Basalt + bamboo+ glass+30 % (SiC)

Fig (12-16) showing Extension vs. load graphs for the flexural tests

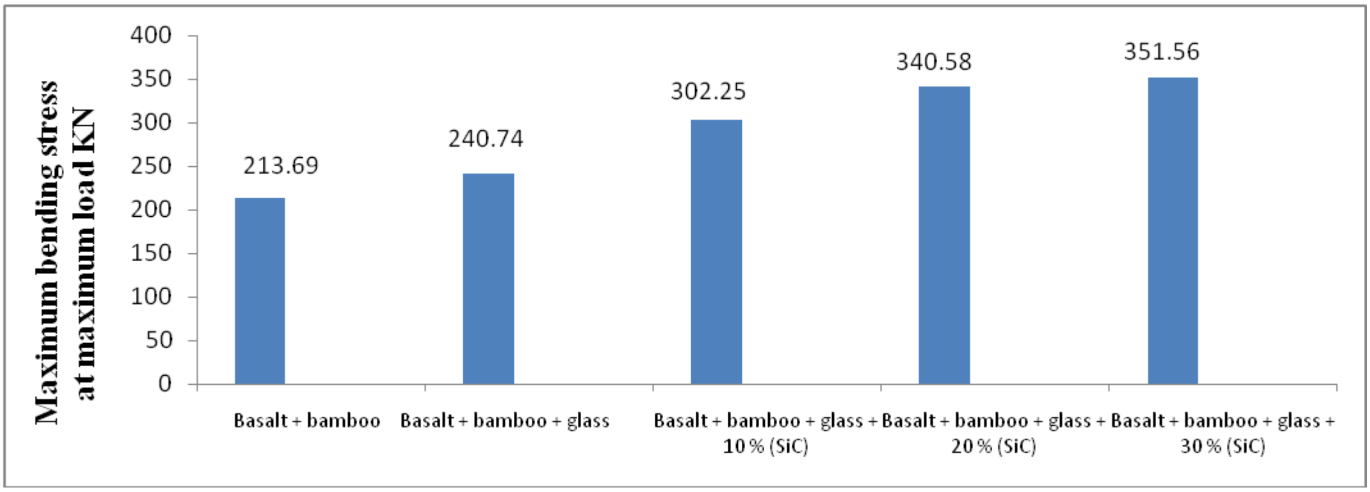


Chart - 3: Comparison for maximum flexural strength

From the graphs it's clear that the flexural strength has increased with the addition of filler materials in the matrix. The crack propagation initiated through an impact will be resisted by the filler materials and they act as crack arrestors. This is mainly due to the increased loading in the composites due to the addition of the (SiC), which improves the bonding strength in the composites by forming stronger bonds with the epoxy matrix and the reinforcement which increase the fracture resistance and helps in improving the flexural property of the composite.

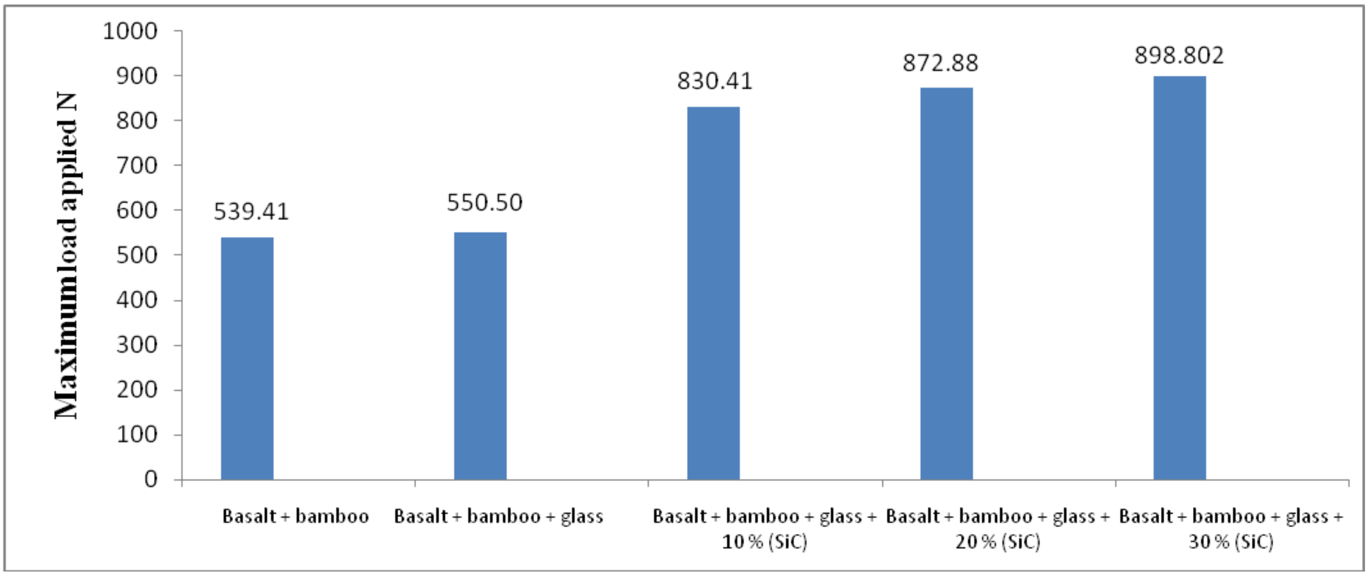


Chart - 4: Comparison for maximum load applied

4.3 Impact test

The impact test is a method used to determine the toughness and notch sensitivity of a material. It reveals the toughness of materials. Brittle materials have low toughness as a result of the small amount of plastic deformation that they can endure. The impact value of a material can also change with temperature. Generally, at lower temperatures, the impact energy of a material is decreased. The size of the specimen may also affect the value of the Izod impact test because it may allow a different number of imperfections in the material, which can act as stress risers and lower the impact energy.

It is widely used to determine the impact properties of plastics, ceramics and composites. The properties that can be determined are energy absorbed, impact strength and maximum load. In this test, specimen is introduced to impact loading by using a Pendulum impact tester. Specimens are prepared as per ASTM D256 standard.

Table 3: Impact test results for natural and hybrid composite

Materials	Charpy Impact Strength (KJ/m2)
Basalt+bamboo	93.66
Basalt + bamboo + glass	95.08
Basalt+bamboo+glass+10%(SiC)	140.24
Basalt+bamboo+glass+20% (SiC)	160.23
Basalt+bamboo+glass+30% (SiC)	168.44

All the specimens being tested have a fixed orientation of 0°. For the specimen of (Basalt + bamboo + glass) the impact strength is 95.08 KJ/m2. Now when 10% silicon carbide is added to the resin matrix with the same combination of matrix and reinforcement materials the impact strength raises to 140.24 KJ/m2. And further when the silicon carbide's content is increased up-to 20% the impact strength increases to a value of 160.23 KJ/m2. Thus the addition of silicon carbide in the matrix shows that the impact strength has increased this is because silicon carbide forms numerous bonds with the matrix and reinforcement material. Hence the energy required for distorting the material increases, thus stronger and enormous number of bonds in the material the energy of impact strength also increases. And when the concentration of (SiC) is increased to 30% in the resin system the impact strength increases to 168.44 KJ/m2. The specimen of combination (Basalt+bamboo) the impact strength is the lowest among the tested combination which is 93.66 KJ/m2 which is mainly because of the absence of E-glass fiber and silicon carbide. This signifies the effect of silicon carbide in the matrix material.

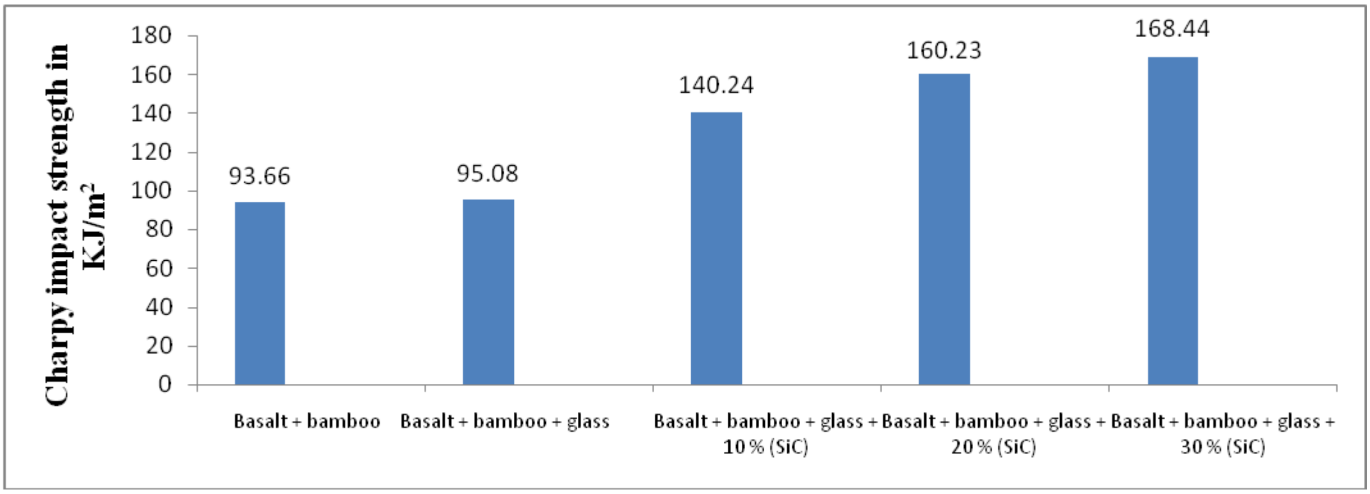


Chart - 5: Comparison of Impact Strength

4.4 Hardness test

Hardness is a typical property of a material. Hardness is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation caused on the surface of the test material. More simply put, when using a fixed force (load) and a given indenter, the smaller the indentation, the harder the material. All the specimens are maintained at a uniform orientation of 0°. From the above table, RHN for the combination of Basalt+bamboo+glass+30% (SiC) is 82, which is more than that of specimens having concentration of silicon as 10% and 20%. The least RHN is for the combination of (Basalt + bamboo) i.e. 70. And when E-glass fiber is present along with the combination of (Basalt + bamboo) the RHN is 72 which signifies the strength imparted by the E-glass fiber to the composite.

From the above results the significance of adding (SiC) in the composite matrix can be seen. This is mainly due to the good bonding with the reinforcement and the epoxy which transmit the entire load to the strong and rigid fibers.

Table 4: Impact test results for natural and hybrid composite

Materials	Hardness(RHN)
Basalt+bamboo	70
Basalt + bamboo + glass	72
Basalt+bamboo+glass+10%(SiC)	76
Basalt+bamboo+glass+20% (SiC)	80
Basalt+bamboo+glass+30% (SiC)	82

All the specimens are maintained at a uniform orientation of 0°. From the above table, RHN for the combination of Basalt+bamboo+glass+30% (SiC) is 82, which is more than that of specimens having concentration of silicon as 10% and 20%. The least RHN is for the combination of (Basalt + bamboo) i.e. 70. And when E-glass fiber is present along with the combination of (Basalt + bamboo) the RHN is 72 which signifies the strength imparted by the E-glass fiber to the composite.

From the above results the significance of adding (SiC) in the composite matrix can be seen. This is mainly due to the good bonding with the reinforcement and the epoxy which transmit the entire load to the strong and rigid fibers.

When the particulates are included the bonding strength is much better and stronger than that of the composite without particulate filler material which is evident from the above graph. The voids are very much filled and the material is strengthened with the inclusion of (SiC) in the matrix and as the concentration of (SiC) is increased the hardness is increased and then at 30% of (SiC) the rise is negligible when compared with that of 10% and 20% specimens since the extra particles in the matrix behave as a lump and disturb the load distribution and overall loading is increased to overcome the strength thus only a small increase in value is seen.

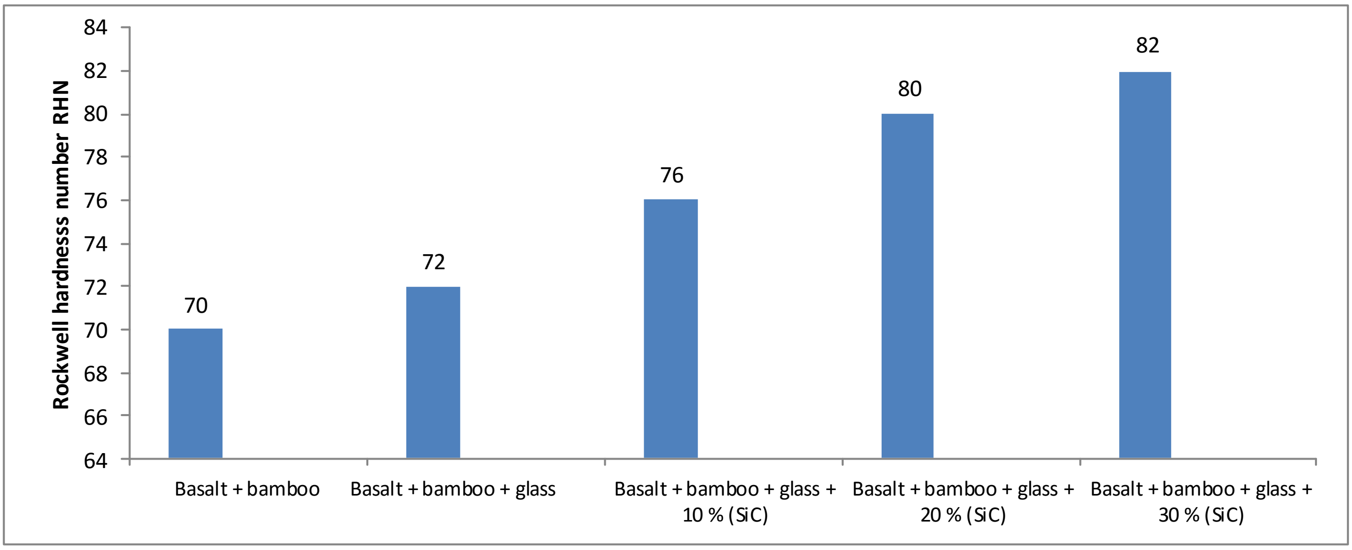


Chart - 6: Comparison by Rockwell Hardness Number

4.5 Specific gravity test

The specific gravity testing is very useful in determining yield and comparing different materials. Specific Gravity means the ratio of the mass of a specimen to that of an equal volume of a standard substance. The composite material of the combination (Basalt+bamboo+glass+30% (SiC)) has the highest density among the tested specimens. This is due to the increase of concentration of silicon carbide in the composite material as compared to that of specimens having 10% and 20% of silicon carbide respectively. The lightest among them is the combination of (Basalt + bamboo) which has a value of 1.33.

Table 5: Density test results for natural and hybrid composite materials

Materials	Density
Basalt + bamboo + glass	1.40
Basalt+bamboo+glass+10%(SiC)	1.41
Basalt+bamboo+glass+20% (SiC)	1.43
Basalt+bamboo+glass+30% (SiC)	1.45
Basalt+bamboo	1.33

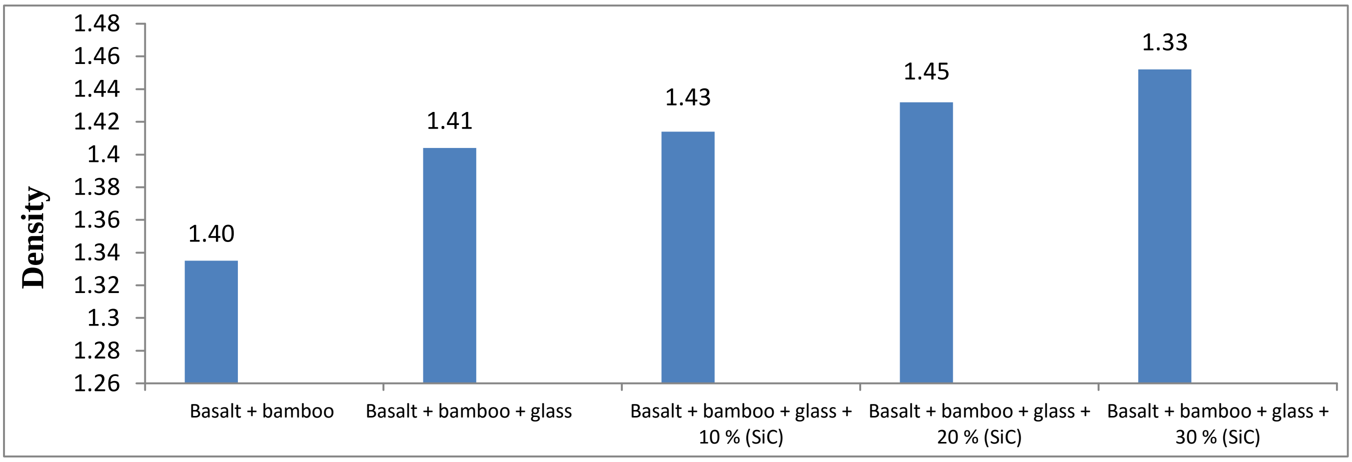


Chart - 7: Comparison based on density of materials

5. CONCLUSIONS

The natural hybrid composites consisting of (bamboo fiber, basalt fiber, and E-glass fiber) are fabricated using epoxy resin as the matrix system with Silicon carbide as the particulate filler with the traditional hand lay-up process. The concentration of silicon carbide is varied in each of the fabricated composites and the mechanical properties such as tensile, flexural, impact, hardness and density are determined experimentally. The orientation of the fibers during fabrication is maintained at 0º throughout the process.

The results states that the particulate filled hybrid composite materials have greater mechanical properties when compared with composite materials without particulate reinforcements. When tensile tests were carried out hybrid composites showed the highest ultimate tensile stress than the other composite materials.

From the results obtained it can be concluded that the particulate filled composite matrix have a good potential with overall improved properties. The inclusion of silicon carbide in the matrix has shown that the voids present in the composites can be filled by these particulates which improve the void content and also improve overall strength by forming stronger bonds with the matrix and the reinforcements.

It was also seen that 30 wt. % Silicon carbide reinforced composites had better performance than that of 10 wt. % and 20 wt. % particulate reinforced composite, which implies that the addition of particulates are desirable till a certain extent and when the limit is exceeded the increase of strength is in a smaller quantity. That is due to the fact that the bonds when formed between particles and reinforcements are much stronger than that of the bonds formed between particles themselves i.e. the particle and reinforcement interaction is stronger than that of the particle-particle interaction, which happens when more amount of particles are present in the matrix.

Thus particulate reinforced composites have good overall mechanical properties and improved performance which would cater the needs of the modern industry. The cost of manufacturing can be effective when manufactured in bulk quantities thus making it one of the better choices to be used for enhanced and stabilized performance.

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