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Fabrication and Performance Test of Glass-Bamboo Fiber Based Industry Safety Helmet

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Abstract: In this 21st century, the interest in using natural fibers as reinforcement in polymer composite material has increased significantly. Now this natural fiber based composite manufacturing has been a wide area of research and it is the most preferred choice for its superior properties like low density, stiffness, light weight and possesses better mechanical properties. All helmets attempt to protect the user's head by absorbing mechanical energy and protecting against penetration. Industrial helmet is essentially made up of polyethylene thermoplastic. In this study, an attempt has been made to fabricate bamboo-glass fiber based polymer composite helmet and investigate its performances. For this helmet, the materials were chosen epoxy resin (ADR 246 TX) as the matrix and bamboo mat and glass fiber as reinforcement. The construction of the helmet is done by using hand lay -out techniques. The helmets thus made were tested for their mechanical properties like compression and impact test. Visual analysis of the helmets shows that hand lay - out techniques provides a reliable process to make a perfect helmet. The performance test results indicate that bamboo-glass fiber based polymer helmet has a sustainable strength over polythene thermoplastic for the application of industrial safety helmets. Cost analysis indicate that using this helmet cost saving more that 30% can be achieved.

Keywords: Industry Safety Helmet, Glass and Bamboo Fiber, Polymer Composite, Hand Lay Out Method

1. Introduction

Technological development in recent decades natural plant fibers use improved due to low density, good thermal insulation, enhance mechanical properties, durability and sustainability. Bamboo is one of the most important natural fiber plant due to its rapid growth rate, biodegradability, and universality. Bamboo fiber has hydrophilic nature so the improvement of interfacial surface adhesion different types of additives, coatings, epoxy resin glass has mixed. As compared to conventional materials, i.e., wood, concrete, and steel, glass fiber provide the advantages of high stiffness or strength to weight ratio with bamboo fiber. Glass fiber has high heat resistance capacity and relatively high strength [1]. A number of studies have shown the feasibility of using bamboo-epoxy composites as structural materials [2-4]. There has been a significant amount of work done in the past on bamboo epoxy composites. Tensile strengths of around 110MPa and flexural strengths of around 130 MPa were obtained. Jindal [5] tested the tensile strength, impact strength and Young's modulus of elasticity of bamboo-fiber reinforced plastic composites. He found that bamboo composites have high strength and ductility and are useful for many structural applications. Shin et al [6] and Okubo et al [7] concluded that bamboo fiber reinforced epoxy composites possess reasonably good mechanical properties, comparable to ordinary glass fiber composites and warrants its use as a structural material. Various forms of bamboo such as strand-form, fiber-form, and particle-form combined with cement, plastics and plywood have been used in applications such as low-rise construction to resist earthquake and wind loads [8, 10]. In our previous work, results indicated that natural fiber can be a very potential candidate in making of composites, especially for partial replacement of high-cost glass fibers for low load bearing applications [11-12]. Raj and Venkateshwarlu [13] have prepared bamboo based ferro-cement slab elements for roofing/flooring purpose in low cost housing. Kankam et al. [14] found its application in reinforced concrete slabs Hence, with this back ground, it is concluded that, the composites stand the most wanted technology in the fast growing current trend. Therefore it is worthwhile to explore the possibility of utilizing cheaper material such as natural fiber like jute, bamboo, rice husk etc. as reinforcement. The present work focused on the fabrication of bamboo-glass fiber based polymer composite helmet by using hand layout method. Later the mechanical performances of this helmet have been investigated by experimentally.

2. Materials and Methods

2.1. Material Collection

In this study, glass fiber and woven bamboo mats were used as reinforcement where the bamboo is stripped into narrow strips, about 2.25mm wide and about 0.4 mm in thickness. The shape of the helmet is made by this stripped bamboo and collected from Bashuri village, Jessore, Bangladesh and are readily available is shown in figure 1. The process of stripping the bamboo and making mats uses neither chemicals nor fuel-based energy. Thus, the process is non-polluting and provides income-generation opportunities to rural-based artisan communities. The epoxy resin (ADR 246 TX) was used as the matrix. Hardener ADH 160 and Methyl Ethyl Ketone Peroxide (MEPOXE) were used to improve the interfacial adhesion and impart strength to the composites. The hardener and resin were purchased from a chemical company and glass fiber were collected from local market. Mechanical properties of glass fiber, bamboo strip and epoxy resin are shown in Table 1.

Table 1. *Mechanical Properties of fiber and matrix.*

Material	Young Modulus E (GPa)	Poisson's ratio	Density (kg/m^3)
Epoxy Resin	2.68	0.4	1150-1200
Glass Fiber	72	0.21	2550
Bamboo Fiber	15.5	0.39	1400

(a) Bamboo strip (b) Bamboo helmet

Figure 1. *Bamboo helmet.*

2.2. Fabrication Procedure

There are many techniques available in industries for manufacturing of composites such as compression molding, vacuum molding and resin transfer molding. The hand lay-up process of manufacturing is one of the simplest and easiest methods for manufacturing composites. In this study, the composites were manufactured by the hand lay-up process. During the fabrication process, the patterns bamboo helmet was impregnated with unsaturated epoxy resin. First the bamboo helmet was laid down, followed by a quantity of liquid resin epoxy poured onto it. Brushes and hand rollers were used to remove any void in the fiber structure and to spread the resin evenly throughout the fibers. Then the glass fiber were laid down on the helmet, followed by a quantity of liquid resin epoxy poured onto it. Finally, brushes and hand rollers were used to remove any void in the fiber structure and to spread the resin evenly throughout the fibers. The composite helmet were cured by exposure to normal atmospheric conditions. The image of the total fabrication process is shown in figure 2. The fabricated composites were cut using a grinding machine to obtain the dimensions of the specimen for mechanical testing as per the ASTM D3039 standards.

Figure 2. *Complete sequential process for fabrication.*

2.3. Experimental Procedure

Visual analysis of the helmets shows that hand lay out process provides a reliable process to make parts, especially ones without acute angles or small radii of curvature. The helmets thus made were tested for their mechanical properties. The impact test on the helmet was performed by a drop test where the helmet was placed on a platform and a 3.4 Kg weight was dropped on it from a height, traveling at 9.9 m/s on impact. The test is run such that the impact occurs at different positions – the resulting damage is observed and quantified. A weight of 3.4 kg was chosen since it approximates the weight of a brick that is use for construction purpose. The tensile test was performed using an electro-mechanical testing machine equipped with the maximum capacity of the load cell at 3 kN. The tensile tests were conducted with a displacement rate 2 mm/min. The specimens were placed in the grip of the tensile testing machine and the test was performed by applying tension until failure at room temperature. The corresponding load and strain obtained were plotted on the graphs. The strength was calculated from the maximum load at failure of the tensile stress. Flexural testing commonly known as three-point bending testing was also carried out as per ASTMD790. Composite specimens of dimensions 120 × 20 × 4 mm were horizontally placed on two supports and load was applied at the center. The deflection was measured by the gauge placed under the specimen, at the center. Impact testing was carried out on Tinius Olsen machine as per procedure mentioned in ASTM D256. Composite specimens were placed in vertical position (Izod Test) and hammer was released to make impact on specimen and CRT reader gives the reading of impact strength. All experimental tests were repeated four times to generate the data. Test specimen for tensile and flexural test are shown in figure 3.

Figure 3. *Test specimen for tensile and bending test.*

3. Experimental Results and Discussions

3.1. Weight Drooped Test Results

In this weight dropped test first the composite helmet was dropped from different height and visual observations were made. The results shown in table 2.

Table 2. *Helmet drooped test results.*

Dropped Height	Photograph After Dropped Test	Visual Observation
6 m		No significance damage or dent observed
8 m		No significance damage or dent observed
10 m		No significance damage or dent observed

As seen in table 2, no visible damage to helmet and no dents were seen. The impact test on the helmet was performed by a drop test where the helmet was placed on a platform and a 3.4 Kg weight was dropped on it from a height, traveling at about 10 m/s on impact. The weight dropped test results shown in Table 3. From this results, there is no visible damage to helmet and no dents were seen. That's mean this composite helmet can be used as industry safety helmet.

Table 3. *Weight drooped test results of composite helmet.*

Weight Dropped Height (m)	Time (s)	Velocity (m/s)	Photograph after Weight Dropped	Visual Observation Remarks
5.5	1.05	10.29		No significance damage or dent observed
9.1	1.36	13.33		No significance damage or dent observed

3.2. Mechanical Properties

The composite specimen samples are tested in the universal testing machine (UTM) and the samples are left to break till the ultimate tensile strength occurs. The tensile stress and displacement curves measured by the tensile test for composite specimens is shown in Figure 4. From this figure it can be seen that due to the high stiffness of bamboo fiber the stress/strain curves becomes steeper. The flexural stress and displacement curves measured by the three point bending test for composite specimens are shown in Figure 5. From this figure it can be seen that due to the high stiffness of bamboo fiber the stress/strain curves becomes steeper.

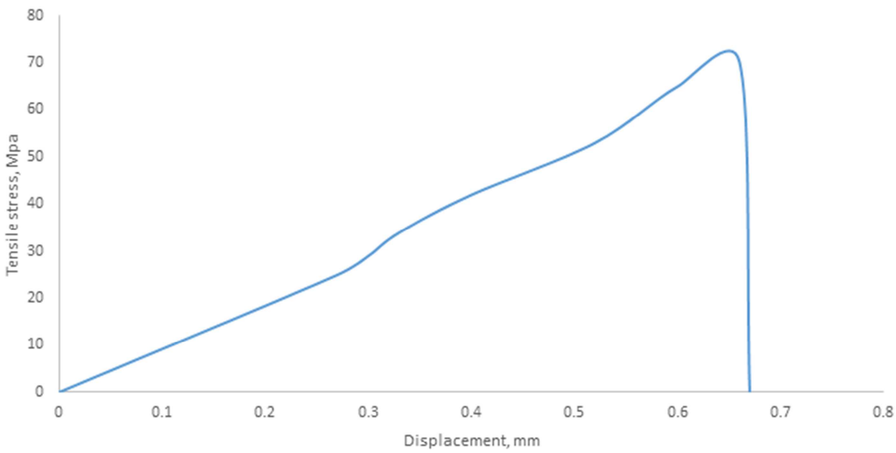

Figure 4. *Tensile stress vs. displacement curve for glass-bamboo based composite.*

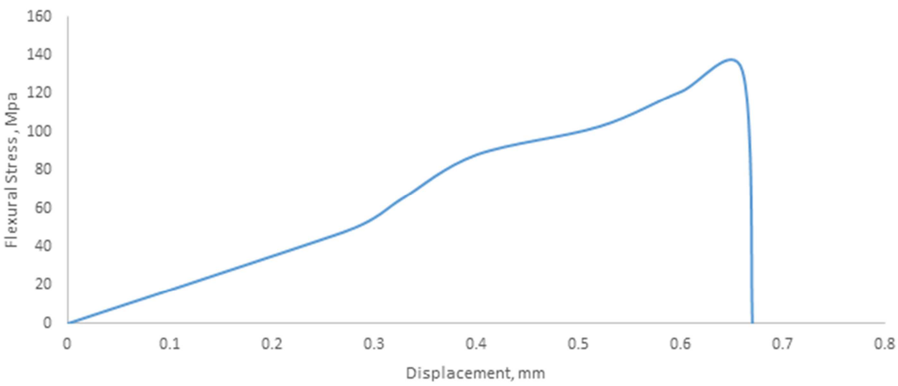

Figure 5. *Flexural stress vs. displacement curve for glass-bamboo based composite.*

Table 4. *Mechanical properties of glass-bamboo-epoxy composite.*

Test	Properties	Comparable Materials (ABS Plastic) [9]
Tensile strength	77 MPa	44 MPa
Flexural strength	132 MPa	70 MPa
Impact Strength	200 kJ/m^2	130 kJ/m^2
Hardness-Rockwell	R 98	R 105

The comparison results of mechanical properties of glass-bamboo-epoxy composites and engineering plastic material is shown in table 4. As seen in Table 4, the mechanical properties of the material are good – superior, or comparable to numerous engineering plastics used in the industry.

3.3. SWOT Analysis

SWOT analysis usually performed for evaluating the various factors like strength, weakness, opportunities and threads of any specimens. Now, here for measuring the strength, weakness, opportunities and threads of the bamboo made helmet the SWOT analysis has been done, that seen in figure 6. The Strengths are Light weight, cost effective, Environment friendly, better mechanical properties. The weakness are hand layout process and low density. The opportunities are vast use of natural fiber and design can be updated easily. The threads are, if the ratio of resin and hardener can't use properly the mechanical properties can be changed rather than expected.

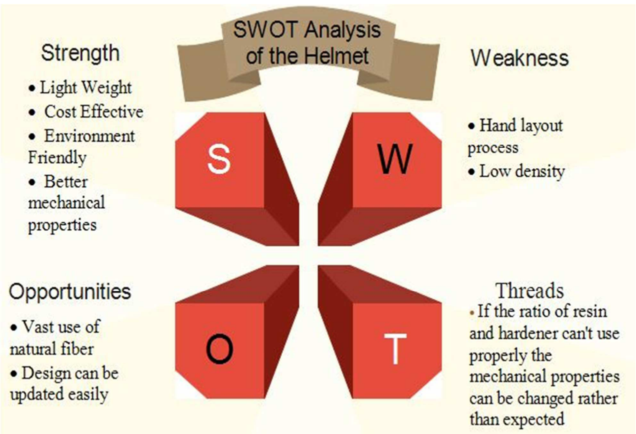

Figure 6. *SWOT Analysis of bamboo made helmet.*

3.4. Cost Analysis

Materials cost for Glass-bamboo-epoxy composite helmet.

Table 5. *Price of fiber in context of Bangladesh.*

Type of fiber	Price / Kg ($)
Bamboo	$ 0.20
Glass fibers	$16.25

Table 6. *Cost analysis of composites (30% Bamboo fiber + 70% Glass fibers).*

Item	Price, $
Bamboo helmet	1
Glass fiber	1
Epoxy Resin	2
Making cost	1
Other Accessories	2
Total	7

Table 7. *Cost analysis of composites (30% Bamboo fiber + 70% Glass fibers).*

Type of helmet	Price, $
Glass-bamboo-epoxy composite helmet.	7 $
ABS safety helmet	10~12 (Market price)

Results of this study show that mechanical properties of this composite helmet material are good – superior, or comparable to numerous engineering plastics used in the industry. The cost analysis of making our investigated composite helmet is shown in Table 5, Table 6 and Table 7. In local market the price of glass fiber and Bamboo fiber is given in Table 5. The cost analysis results shows that the total cost reduced about 30%.

4. Conclusions

In this study, an attempt has been made to fabricate bamboo-glass fiber based industry safety helmet and investigate its performances. Tensile strength, impact strength and flexural strength values are identified. After determining the material properties of natural fiber reinforced composite using compressive test and impact test, the composites showed comparatively better performance. The results showed that industrial safety helmet can be made with bamboo-glass–epoxy composite to achieve increased mechanical properties and reduced cost. So finally it can be concluded that natural fiber (Bamboo) which is easily available in mass without paying any amount can successfully replace the costly and non-renewable synthetic fiber (glass fiber) in many applications. Thereafter bamboo fiber can be a very potential candidate in making of composites, especially for fully replacement of high-cost glass and carbon fibers for low load bearing applications. For future scope, similarly the composite can be prepared a hybrid composite by adding different natural fibers such as jute, hemp, coconut etc. Can also do the SEM analysis for this composites.

References

[1] Hofer, S., M. Gediminas, V. Malhotra, "Natural Fiber – phenolic – hannebachite composites: effects of fiber type", ANTEC (2010), 213-217.

[2] Jain, S & Kumar R. "Processing of bamboo fiber reinforced plastic composites", *Mater. Manuf. Processes 9 (1994), pp. 813-828.*

[3] Kumar, V. & R. Kumar: “Improved Mechanical and Thermal Properties of Bamboo-Epoxy Nano composites”. Journal of Polymer Composites, 33 (2012) pp. 362-370.

[4] Mohanty S., Gupta S. etc. A report on “Bamboo as a green engineering material in rural housing and agricultural structures for sustainable economic growth”. Published under the aegis of “Indian Council of Agricultural Research (ICAR)”.

[5] Jindal, U. C. “Development and testing of bamboo-fiber reinforced plastic Composites”, J. Compos. Mater. 20 (1986), pp. 19-29.

[6] Shin, F. G., Xian, X. J., Zheng W. P. and Yipp, “M. W. Analysis of the mechanical Properties and microstructure of bamboo-epoxy composites”, J. Mater. Sci. 24 (1989), pp. 2483-3490.

[7] Okubo, K., Fujii T. and Yamamoto Y. “Development of bamboo-based polymer composites and their mechanical properties”, Composites: Part A., 35 (2004), pp. 377-383.

[8] Lee, A. W. C., X. S. Bai, and P. N. Peralta. “Physical and mechanical properties of strand board made from moso bamboo”, Forest Prod. J. 46 (1996), pp. 84-88.

[9] Reference for ABS plastics: https://www.plasticsintl.com/datasheets/ABS_FR.pdf

[10] Adekunle P. Adewuyi, Adegboyega A. Otukoya, Oluwole A. Olaniyi, Oladipupo S. Olafusi, Comparative Studies of Steel, Bamboo and Rattan as Reinforcing Bars in Concrete: Tensile and Flexural Characteristics. Open Journal of Civil Engineering, 2015, 5, 228-238.

[11] Md. Rafiquzzama, Md. Maksudul Islam, Md. Habibur Rahman, Md. Saniat Talukdar and Md. Nahid Hasan. 2016. Mechanical property evaluation of glass–jute fiber reinforced polymer composites. Polymers Advance Technologies. 27: 1308-1316.

[12] Md. Rafiquzzaman, S. Abdullah, and A. M. T. Arifin. 2015. Behavioural observation of laminated polymer composite under uniaxial quasi-static and cyclic loads. Fibers and Polymers. 16: 640-649.

[13] Venkateshwarlu, D. and Raj, V. (1989) Development of Bamboo Based Ferrocement Roofing Elements for Low Cost Housing. Journal of Ferrocement, 19 (1989), 331-337.

[14] Kankam, J. A., Ben-George, M. and Perry, S. H. (1988) Bamboo-Reinforced Beams Subjected to Third-Point Loading. ACI Structural Journal, 85, 61-67.