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Prediction of Tensile strength on Hybrid Composite of Basalt Fiber with Titanium Oxide, Barium Sulphate and Silicon Carbide

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Abstract: Today a significant growth is observed in the manufacturing of composite materials. Intensively developed polymer composite materials (PCM) are used in different sectors of industry and technology. They are successfully replacing traditional construction materials and also permit the conditions that exclude use of metals. By industrial production of basalt fibers on the basis of new technologies their cost is equal and even less than cost of glass fiber, moreover basalt fibers and materials on their basis have the most preferable parameter, a ratio of quality and the price in comparison with glass & carbon fibers, and other types of fibers. Though Basalt fiber has good wear resistance still increasing the wear resistance, decreasing friction coefficient, and increasing the hardness also gives more applications to basalt fiber like car brakes, interior decorations, car headliner, etc. more over increase in basalt fiber's tensile strength will give more applications to basalt fiber like bridges, underground tunnels, etc. From the results, it can be concluded that adding titanium oxide, silicon carbide and barium sulphate to the fiber matrix shows the increase in the above said properties, thus the above said mixture are added to the basalt fiber. The previous literature survey shows that adding titanium oxide, silicon carbide and barium sulphate to the fiber matrix shows the increase in the above said properties, thus the above said mixture are added to the basalt fiber. The tensile test will be conducted as per the ASTM standards on the Instron machine, the impact testing will be done on the charpy impact testing machine and the hardness testing will be conducted on the Rockwell hardness machine.
Keywords: Basalt fiber, tensilestrength, Instron machine, Rockwell hadness.

1. Introduction

Hybridization is a commonly used procedure to obtain properties, which are intermediate between the two originating materials. Dealing with polymer composites, hybridization may result in a compromise between mechanical properties and cost to meet specified design requirements, as one of the reinforcements is usually cheaper than the other one. A number of studies have been performed recently, which suggest that mechanical properties can be possibly tailored using hybridization based on glass or basalt fiber laminates and including other natural (aiming at a more sustainable material) or synthetic fibers. In particular, with respect to plant fibers, which equally show thermal and acoustic insulation properties, the higher specific weight of basalt fibers (around2700 kg/m^3) is widely compensated by their higher modulus, excellent heat resistance, good resistance to chemical attack and low water absorption. This suggests that hybrid laminates, based on basalt fibers and plant fibers, and/or glass–plant fiber hybrid laminates, the latter being particularly studied when it comes to the need for sufficient impact resistance, may have some interest. This would possibly result in a more sustainable end-of-life scenario without substantially affecting the structural performance of the laminates.

As a matter of fact, hybridization of basalt fibers has been attempted with ceramic fibers, to provide improved hot wear resistance to friction materials, with high tensile strength fibers, such as carbon and aramid, and with glass fibers. In these cases, basalt provided an impact and environmental resistance superior to that provided by the corresponding hybrids with glass fibers, coupled with a substantial reduction in costs, with respect to carbon and aramid fiber composites. In the case of basalt/Nylon fibers hybrid laminates, low tensile modulus of Nylon is improved by adding basalt fibers, whilst Nylon provides conversely a higher impact resistance. Also basalt hybridization with glass fibers has been attempted, which is based on the use of two fibers, which are chemically not very different. Basalt fibers possess good tensile strength[1].

Though Basalt fibers tensile strength is higher than other fibers but still increase in basalt fiber's tensile strength will give more applications to basalt fiber like post-earthquake strengthening, bridges, underground tunnels etc. Moreover reducing the wear resistance, friction coefficient, and increasing the hardness also gives more applications to basalt fiber. Thus to increase its tensile strength we are adding Titanium oxide and Aluminium oxide to basalt fiber in proportion of 5% weight[3]. We are also adding Barium sulphate to basalt fiber in 5wt%, we are also adding Silicon carbide in 5wt% to increase the hardness[2] and we are also adding 2wt% of graphite to reduce coefficient of friction[4].

Basalt originates from volcanic magma and flood volcanoes, a very hot fluid or semifluid material under the earth's crust, solidified in the open air. Basalt is a common term used for a variety of volcanic rocks, which are gray, dark in colour, formed from the molten lava after solidification. Basalt rock-beds with a thickness of as high as 200 m have been found in the East Asian countries. Russia has unlimited basalt reserves. There are large deposits of these rocks in the Ural, Kam, chatka, Far East, Sakhalin, Kola Peninsula, Northwest Siberia, and the Transcaucasia. Basalt fiber is a material made from extremely fine fibers of basalt, which is composed of the minerals plagioclase, pyroxene, and olivine. Plagioclase is an important series of minerals within the feldspar family. The pyroxenes are a group of important rock-forming inosilicate minerals found in many igneous and metamorphic rocks. In silicates (from Greek, fiber), or chain silicates, have interlocking chains of silicate tetrahedra with either SiO3, 1:3 ratio, for single chains or Si4O11, 4:11 ratio, for double chains. Igneous rock is formed through the cooling and solidification of magma or lava.

Metamorphic rock is the result of the transformation of an existing rock type, the protolith, in a process called metamorphism, which means "change in form". The mineral olivine is a magnesium iron silicate with the formula (Mg,Fe)2SiO4. The mineral levels and chemical makeup of basalt formations can differ significantly from location to location. Moreover, the rate of cooling, when the original flow reached the earth's surface, also influenced the crystal structure. Its ready availability from mines and open-air quarries around the world, only a few dozen locations contain basalt that has been analyzed and qualified as suitable for manufacture of continuous thin filaments. Basalt formations in the Ukraine are particularly well suited to fiber processing.

Basalt Rock fibers have no toxic reaction with air or water, are non-combustible and explosion proof. When in contact with other chemicals they produce no chemical reactions that may damage health or the environment. It has good hardness and thermal properties, can have various application as construction materials. Basalt is a major replacement to the asbestos, which poses health hazards by damaging respiratory systems. Basalt base composites can replace steel (1 kg of basalt reinforces equals 9.6 kg of steel) as light weight concrete can be get from basalt fiber. As it is made of basalt rock is really cheap and has several excellent properties[5-7].The major advantages of Basalt fiber are

- 20-25% higher tensile strength than E-glass [8]
- 10-15 % higher tensile modulus than E-glass [9]
- Better chemical resistance than regular E-glass
- Extended temperature range up to 580°C
- Environmental friendliness and easy recycling/disposal of basalt-fiber-reinforced plastics (BFRP) compared to GFRP [10]

The main objective of the paper is to increase the tensile strength, hardness, wear resistance and decrease friction coefficient. Thus it will be used in many applications like post-earthquake strengthening, bridges, underground tunnels etc. Moreover basalt fiber is cheap when compared to glass fibers, thus if this purpose is satisfied this can bring a new revolution in the composites. The main purpose of the paper is to produce a composite with basalt fiber as the core material and adding other materials like aluminium oxide ,titanium oxide, Barium sulphate, silicon carbide and graphite to form a composite which has more tensile strength than basalt fiber, higher wear resistance than basalt fiber, lower coefficient of friction and higher hardness.

2. Experimental

Fabrication Process

1. The major component of basaltfiber is Epoxy LY556 (Resin).
2. Hardener HY951 is used for hardening and support.
3. Resin + Hardener are mixed in the ratio of 10:1 and the mixture made up is called MATRIX.
4. Tool is prepared by standard method.
5. Apply the matrix on glass cloth which is wrapped around the mandrel.
6. Ensure proper weighing is done.
7. Clamp the tool die for 2 hrs at ambient temperature condition.
8. The sample is then furnace heated at 100celcius for 2 hrs for hardening.
9. Take out and cool the specimen until room temp. is achieved.
10. Flash is removed from the sample.
11. Demoulding i.e. clamp is removed from the specimen.
12. Cut to appropriate dimension as per experimental needs
13. Emery paper of grade 60 is used to provide necessary surface finish.

The Figure1, Figure 2 and Figure 3 shows the basaltfiber, mould cavity and hot air oven for preparing specimen.

Figure 1.Basalt Fiber

Figure 2.Mould Cavity

Figure 3. Hot Air Oven

3. Experimental Setup

The Instron 3367 device is a displacement controlled load frame. This means that the crosshead is raised or lowered by turning screws. A picture of the load frame is shown in Figure 4 with parts. Consider the H shaped structure to be the load frame. Below is a description of the various important parts.

A. Crosshead: The part of the load frame that moves during a tensile test, or down during a compression test.
B. Load Cell: Measurement transducer for the load applied. The maximum load this cell is designed for 30 kN.
C. Sample Grips: The sample grips hold the sample during the test. These come in many shapes and sizes, from threaded (shown) to clamps, etc.
D. Upper and Lower Crosshead Limits: Trip switches for the maximum height the crosshead is allowed to travel during a test.

The tensile strength experiment is carried out for five specimen, and the specimen design standard is ASTM D638. The observations are given below.

Technical description of the Equipment Instron Universal testing machine Model 3367 can perform tensile, compression and bending test either in static or dynamic condition. It consists of three main components, which are Load Frame; ServoHydraulic Control Systems and Hydraulic Power Pack.

The load frame consists of two columns with fixed table at the bottom and adjustablecrosshead table at the top. There are two grips available in the frame; lower and upper grips

Which hold the specimens to be tested. The lower grip is located at lower table and is mounted to the actuator and the upper grip is mounted to the load cell on the upper crosshead of the system.

The actuator system is used to monitor the displacement, while the loadcell is used to monitor the load variation during testing of the specimen. In order to insert the specimen, gripping handset is used to operate both grips. This gripping process will be controlled by the servohydraulic control system. Normally, the upper grip will be fixed, but its vertical position can be adjusted to accommodate specimens of different size. The adjustment of the crosshead is done using built in hydraulic lifts and is secured by hydraulic clamp. The powerful hydraulic actuator will be used to drive the lower grips. Once the specimen has been clamped to the grips, the vertical movement of the lower grips generates the desiredloading on the specimen to perform the test. Figure 4 shows InstronTesile Tester. It general specifications are:

- Loadcell capacity: ± 100 kN (dynamic) and ± 120 kN (static)
- Actuator capacity: ± 100 kN (dynamic) with ± 75 mm stroke
- Servovalve capacity: 40 litre per minutes
- Max pressure: 21Mpa
- Specimen thickness: 0 to 7.8 mm (flat)

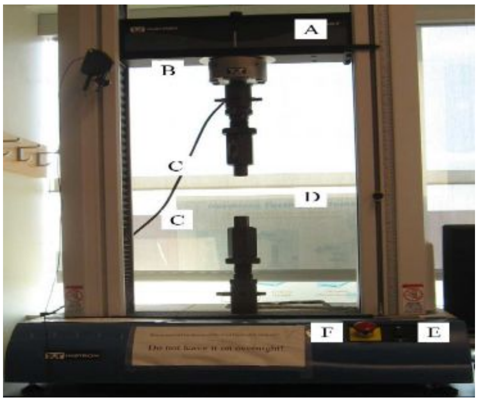

Figure 4 InstronTesileTester

Specimen

The geometry of the specimen depends on type of grip to be used. The specimen to be used in this experiment is rectangular flat specimen. The specimen is prepared according to ASTM D638standard test methods for tension testing of materials.

Procedure

1. Turn on the control panel and computer system. When the system is turned on, the control system will begin a self-test procedure (The system means, the control panel and the computer system). Here, all the system control modules and their microprocessors are individually checked for any fault. The hydraulic system cannot be applied to the system if the fault is found. The upper display of the front panel will indicate the progress of the self-test procedure. Once the test completed successfully the lower display will indicate, " Press any key to continue".
2. Set-up STRAIN 1 and LOAD: Go to area 1, press SETUP-CAL-CAL-AUTO-GO. This is to be performed from the control panel. Repeat the same steps for Load mode. As you press GO, the calibrated lights starts blinking. Wait until it stops blinking to calibrate other modes. STRAIN 2 is not calibrated as it is for further development of the machine and position should not be calibrated as it has a fix value. To do position set-up, certain adjustment inside the load frame cubicles has to be done. Thus, for safety reason, do not calibrate position.
3. Turn ON the hydraulic system by pressing button I follow by button II located on the load frame.Turn ON the cooling water supply.

4. Results and Discussion

The main objective of the paper is to increase the tensile strength, increase the hardness and increase the wear resistance. Thus from the literature survey, a suitable solution has been proposed. The following materials are added to the basalt fiber,

- Titanium oxide
- Barium Sulphate
- Silicon carbide
- Graphite

The above given materials are added to the Basalt fiber in the given weight proportion. The figure 5 shows dimensions of tensile test specimen and Table 1 shows results of tensile test.

4.1 Specimen composition

Different samples prepared are :

- **Sample 1**

- Basalt fiber – 40%
- Epoxy Resin – 60%

- **Sample 2**

- Basalt fiber – 23%
- Titanium oxide – 5%
- Silicon carbide – 5%
- Barium sulphate – 5%
- Graphite – 2%
- Epoxy Resin – 60%

- **Sample 3**

- Basalt fiber – 50%
- Epoxy Resin – 50%

- **Sample 4**

- Basalt fiber – 33%
- Titanium oxide – 5%
- Silicon carbide – 5%
- Barium sulphate – 5%
- Graphite – 2%
- Epoxy Resin – 50%

- **Sample 5**

- Basalt fiber – 50%
- Aluminum oxide – 5%
- Titanium oxide – 5%
- Silicon oxide – 5%
- Epoxy resin – 35%

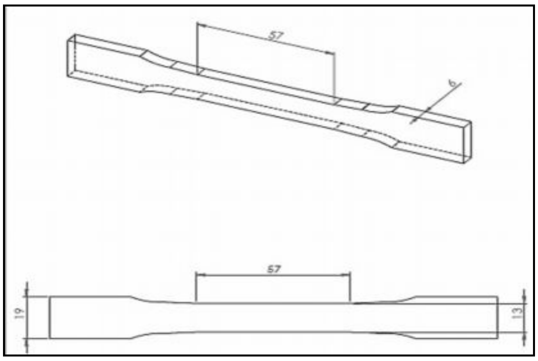

Figure 5 Dimensions of tensile test specimen

4.2 Tensile Test Result

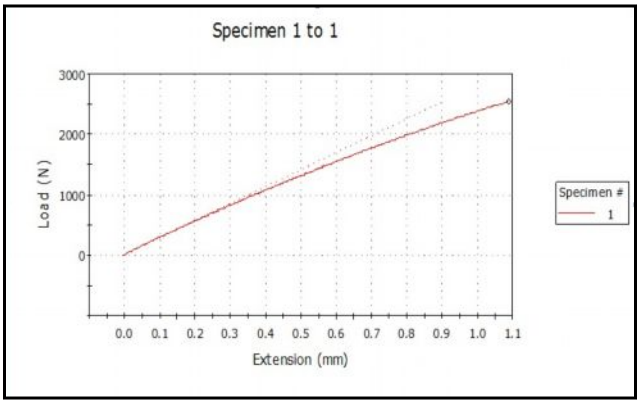

Figure 6 Load Vs Extension for specimen 1

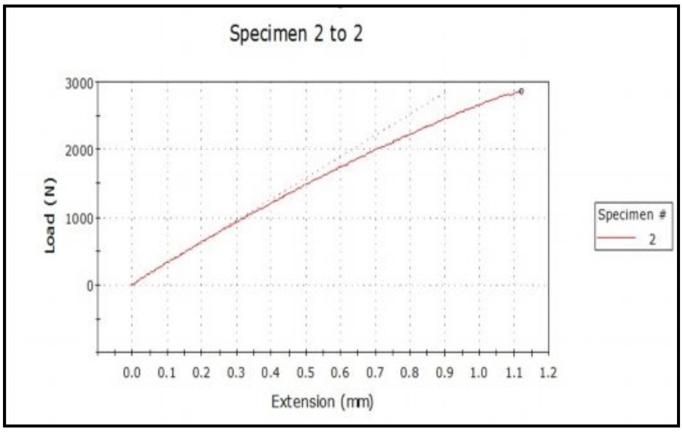

Figure 7 Load Vs Extension for specimen 2

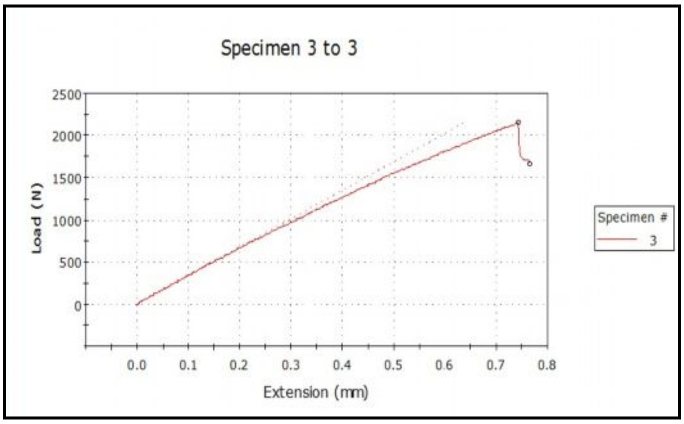

Figure 8 Load Vs Extension for specimen 3

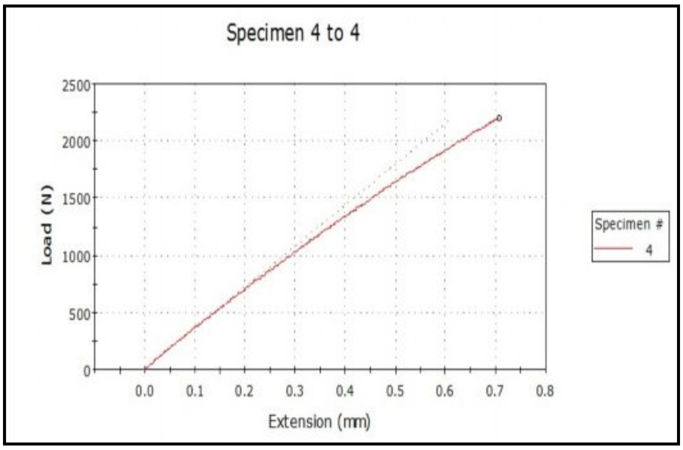

Figure 9 Load Vs Extension for specimen 4

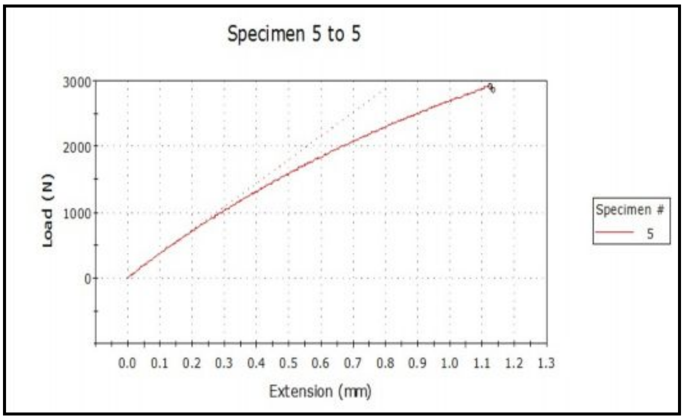

Figure 10 Load Vs Extension for specimen 5

Table 1 Results of Tensile Test

	Specimen label	**Tensile strain at Maximum Load (%)**	**Load at Break (Standard) (kN)**	**Tensile stress at Break (Standard) (MPa)**
1	1	1.24225	2.21	38.31
2	2	1.96793	2.86	48.25
3	3	1.91201	2.55	43.54
4	4	1.97389	2.87	43.78
5	5	1.30537	1.67	29.00
Maximum		1.97389	2.87	48.25
Mean		1.67053	2.21	40.38
Minimum		1.24225	1.11	29.00
	True stress at Maximum Load (Pa)	% Elong. at Tensile Strength at Non-proportional Elongation (Standard) (%)	% Elongation at Break at Non-proportional Elongation (Standard) (%)	Elong. at Tensile Strength at Non-proportional Elongation (Standard) (mm)
1	38790785.40295	1.24225	1.24225	0.70809
2	49202013.16247	1.96793	1.96793	1.12172
3	44473304.87706	1.91296	1.91201	1.09039
4	45294181.63555	0.03307	0.08064	0.01885
5	37886316.15551	0.04050	0.36265	0.02308
Maximum	49202013.16247	1.96793	1.96793	1.12172
Mean	42617613.25823	1.13641	1.19787	0.58018
Minimum	37886316.15551	0.03307	0.08064	0.01885

From the above Figure 6-10 the following results were observed.

- Compared to other specimen, specimen 2 and specimen 4 has higher tensile strength(48.25 MPa& 43.78 MPa).
- Specimen 2 and specimen 4 are the hybrid composite.
- Specimen 1 and specimen 2 are compared as they are having a 40 wt% of hybrid(other wt % is epoxy resin).
- On comparing both specimen 1 and specimen 2 it can be find that specimen 2(hybrid composite) has more tensile strength than specimen 1.
- Specimen 3 and specimen 4 are compared as they are having a 50 wt% of hybrid(other wt % is epoxy resin)

5. Conclusion

- The tensile strength of specimen 1 is lesser when compared to the hybrids and specimen 3(Basalt fiber and resin), 38.31 MPa.Thus specimen is a moderate sample with not so high and not so low properties, thus it can be used in applications where friction is not very high or not very low is required with medium hardness.
- The tensile strength of specimen 2 is the highest when comparing with other specimens, 48.25 MPa. Thus specimen 2 can be used in applications were high tensile strength.
- There is an increase in the tensile strength for the specimen 3 than specimen 1 as it has more basalt fiber but it still has low tensile strength than the hybrid composites. Specimen 3 cannot be used in applications were high strength or hardness is required.

- The tensile strength of the specimen 4 is the second higher than other specimens. Thus specimen 4 can be used in applications where higher tensile strength and hardness is required.
- The tensile strength of specimen 5 is very less when compared to other specimen. Thus the purpose of the paper is to increase the tensile strength, hardness, wears resistance has been achieved. The specimen 2 has satisfied for the applications of all rotating parts.

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