# Significance of Tungsten Carbide Filler Reinforcement on Ultimate Tensile Strength of Basalt Fiber Epoxy Composites

**Kalmeshwar Ullegaddi, Shivarudraiah, Mahesha C R**

***Abstract:** Basalt Fiber Reinforced polymer composite has the best green reinforced alternative to synthetic fibers. It is having an excellent mechanical properties compared to synthetic fibers. Twill weave woven basalt fabric used to manufacture the laminates using Hand layup method preceded with vacuum bag pressure method to obtain the series of unfilled and filled tungsten carbide filler (0-8%) materials into basalt epoxy composites. In this study, tensile strength and percentage of elongation of laminated structure carried out using computerized universal testing equipment. Among these laminates, the basalt fiber reinforced with 6% of tungsten carbide filler shows better strength properties than the other combination of laminates. The incorporation of tungsten carbide fillers in epoxy composites could provide a synergism in terms of improving tensile properties and percentage of elongation.*

***Keywords:** Basalt Fiber, Tungsten Carbide, Ultimate Tensile Strength, and Vaccum Pressure Method.*

## I. INTRODUCTION

Researchers always finding a new material suits the desired application and environmentally friendly. Composite material satisfying the need of new material with excellent properties that the earlier product. A composite material is named as two or more physical mixture of different constituent material or chemical mixtures of the same or combination of both. It results in component improvement likely as mechanical, thermal and wear properties. The main advantages of composite material are their excellent specific strength, stiffness when compared with another material component concerning weight reduction in the final product.

The main components of composite material are reinforcement and matrix. Reinforcement may be classified as particulate form or fiber form. Usually, reinforcement is available in fabric, sheets and particulate [1]. Matrix is another essential element of composite material. The reinforcement is embedded with the matrix. Matrix is metal, ceramic, or polymer.

The main property of reinforcing element is to give strength and load-bearing properties, whereas matrix provides a binding agent, transfer and distribute the applied load to fibers and helps to retain the position of fibers in a particular direction and orientation.

The Polymer matrix includes the epoxy resins, polyester resins, and phenolic resins [2]. The most important method used in the manufacture of polymer composites are hand layup and Vaccum bag assisted resin transfer method (VARTM).

Polymer composite can be synthetic or natural. Synthetic polymer composite is very expensive and non-biodegradability. To overcome this natural fiber reinforced composite plays an essential role in the present composite world. The composite material is less plastic, toughness, and electric insulation. Polymer composite not able to a wide range of application on their own compared to other composites structure due to its lack of properties. These can be improved by incorporating the filler material, which will improve the properties predominantly. One of the best solutions could be a new natural fiber material which also having exceptional properties, lightweight and minimum risk of bio-degradability [3]. In this sense BASALT fiber is one of the best natural fibers available abundantly in nature.

Basalt is fine-grained, igneous rock comprises of plagioclase, feldspar, pyroxene, magnetite and with or without of olivine. It contains $SiO_2$ in rich content, not more than 53 wt. % and 5 wt. % of traces of alkalis [4]. Basalt mainly classified into two categories, fall into alkali basalt and tholeiites. In both categories, basalt contains the same weight percentage of $SiO_2$, but in the case of alkali basalt quite higher percentage of $NaO_2$ and $K_2O$.

## II. LITERATURE REVIEW

Yang Xiao et al. [5] studied the strength properties basalt fiber reinforced polymer composites filled with calcite filler. The tensile strength of specimen increases predominantly with an increase in the content of calcite percentage, whereas axial strain of the peak failure decreases with increasing calcite percentage. The improvement in ductility has implicated for higher loading condition.

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* Correspondence Author
**Kalmeshwar Ullegaddi***, Research Scholar, Department of Mechanical Engineering, UVCE, Bangalore, India. kalmesh.bdm@gmail.com
**Dr. Shivarudraiah**, Professor, Department of Mechanical Engineering, UVCE, Bangalore, India.
**Dr. Mahesha C R**, Assistant Professor, Department of Industrial Engineering and Management, Dr. AIT, Bangalore, India.

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The bonding effectiveness on tensile strength is studied justified by Scanning Electron Microscope (SEM) images. Zuhaib Ahmad et al. [6], studied on hybrid composite made up basalt and glass fiber epoxy composites. In particular applications like aerospace system, a higher lightweight structure are more in demand. The mechanical properties under constant loading of longer time are more significant importance for sustainability. In this research work, the author studied the hybrid structure made of basalt and glass epoxy with different density, fiber weave direction, stitching distance and different layer thickness. The uniaxial test has been carried out to understand and analyze the significance of basalt epoxy, glass epoxy and hybrid epoxy composites. A detailed study SEM images give epoxy and fiber bonding between basalt and glass fibers.

Jingjing He et al. [7] uniaxial tensile tests carried out on of basalt fiber epoxy composite material with the different four-way orientation of fiber and studied the failure of material for which fiber direction was mostly affected. The results revealed that, when the fiber volume fraction is constant, the tensile strength and elastic modulus and limiting strain all decreases with increasing fiber orientation. When the fiber orientation is constant, the tensile strength and all other limiting properties increase predominantly. A clustering of fiber occurs in exceeding the fiber volume fraction higher than 1.2% and lead to a fail composite sample.

The basalt equidistribution and clustering of fiber content were used to characterize the basalt fiber properties. Fiber volume increases with increase in clustering effect in basalt fiber results in lower tensile properties, whereas in equidistribution of fiber give enhanced tensile properties. Based on Tsai theory, geometric model and tensile test mechanical model of the clustering effect of fiber were established. Both the calculated value and analytical values are close to the experimental values.

Fiore et al. [8], the influence of unidirectional basalt fabric layers/Glass fibers on mechanical characterization performances. The main application for the test is to implicate in a marine application. Polymer composite reinforced glass fiber reinforced laminates prepared by Vaccum Bagging Technique, The bending and tensile test were carried out to evaluate and studied the effect of the number of layers and position of the layer on the mechanical properties of investigated structures. It reveals the presence of two external layers of basalt fiber exhibits more significant mechanical properties of hybrid laminates compared to glass fiber laminates.

## III. MATERIALS

In this present work, Basalt fiber reinforced polymer composites, where twill-directional woven fabric with 350 GSM supplied by Nickunj Pvt. Ltd, Mumbai. Twill fabric for composite applications is entirely made of 100% BCF (continuous basalt filament) roving and properties are as shown in Table. 1. Tungsten carbide material features extreme tensile strength hardness and other properties, as shown in Table. 2. The material is typically forged by the reaction of tungsten (W). Cobalt blends are also used to display better impact resistance over a WC-Ni blend. Epoxy LY556 resin is chosen as matrix due to having better adhesion and higher bonding strength. HY 951 hardener used as a cross-linking agent with 10wt % of fibers.

**Table- I: Technical Parameters of Tungsten Carbide**

| Tungsten Carbide | Properties |
|---|---|
| Molecular weight | 195.9 |
| Color | Grey |
| Physical state | Hexagonal Crystal |
| Melting point (°C) | 2,785°C |
| Boiling point (°C) | 6,000°C |
| Density | 15.6 gm/cm$^3$ |
| Solubility<br>Water nitric acid<br>Hydrogen fluoride | <br>Insoluble<br>Soluble |
| Micro-hardness | 1730 kg/mm$^2$ |
| Hardness | 89.5 HRA |
| Bending strength | 1550 N/mm$^2$ |

**Table- II: Technical Parameters of Basalt Fabric**

| Property | Values |
|---|---|
| Base Material | Basalt Fabric |
| Density of un-sized filament material | 2.63 kg/dm3 |
| Moisture content of basaltic rock | 0.1 % |
| Melting point | 1350 °C |
| Specific surface weight | 350 g/m2 |
| Weave Type | Twill |
| Weft & warp Yarn Specification | 13micron |
| Weft & Warp picks | 5 X 5 (ends/10mm) |
| Sizing type | Silane |
| Moisture content(fabric) | <0.3% |
| LOI (Loss of Ignition) sizing content | <0.4-0.6 % |

## IV. METHODOLOGY

In this present research work, Twill weave basalt fabric considered as reinforcement and epoxy as a matrix. In polymer composite, the orientation of fiber plays a vital role in the strength of the structure. In this present study, we choose twill weave fabric having an orientation in (0°-90°). A typically 11 layers of fabrics used to attain the 2.8 mm t0 3.0 mm thickens as per the ASTM standards. A typical hand layup method is followed by Vaccum bag pressure method is used. An excess amount of resin in the moulds is easily sucked by breather.

It allowed to 1 hour attain proper adhesion between fiber and matrix and is followed to keep the laminate for 24 hours at room temperature post-curing at 100°C for 2 hours. In this present study, two types of laminates were considered, such as basalt fiber with no filler material and basalt fiber filled with different proportion of tungsten carbide filler like weight percentages of 2%, 4%, 6%, and 8% respectively. Laminates are cut into as per ASTM standards using high precision Water Jet Machining operation.

## V. EXPERIMENTAL STUDY

In polymer composite, the most important noted point is to increase the strength of the component. In order to check properties of a component, mechanical testing to be carried out to justify the strength of the component. The fabricated component is to be part of any engineering application. It is a necessity to ensure the load it can bear during loading condition. Hence it is to recommend the researcher to do experimental testing before the commenting on the strength of the component. In this present study, Tensile test been carried out to understand at what extent it can take a load to understand structural integrity concerning strength. Test specimen prepared were 5 types likely basalt fabric with no filler and 2%, 4%, 6% and 8 % tungsten carbide filler weight proportion added to basalt fiber respectively.

### A. Ultimate Tensile Strength

The material ability to resist the load under breaking stress is one of the most important and widely measured properties of the material used in any structural applications. The tensile test carried as per ASTM D 3039 [9] standard and the specimen geometry as shown fig 1. Tensile strength test shows the resistance of polymer component under tensile load. A computerized Universal Testing Machine was used to carry out the tests. UTM having a precision loading condition and extension is set 1.5 mm/min. The specimens were prepared according to ASTM D 3039 standard and edges were softened with emery paper to avoid the sharp edges. A specimen having a length of 250 mm, but gauge length considered for testing is 170mm, means 40mm on both sides left for the jaw to hold/gripping sample. The two analytical results were considered, such as load and displacement, as well as stress vs. strain graph plots. The results were calculated on an average of 3 samples.

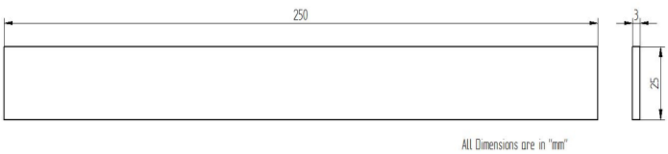


**Fig. 1. ASTM –D 3039 (Uni-Axial Tensile Test)**

**Table- III: Composition Details with sample code of laminates**

| Composition | Fiber Wt.% | Epoxy Wt. % | Filler Wt.% |
|---|---|---|---|
| Basalt Epoxy (B-E) | 60 | 40 | 0 |
| B-E + 2% WC | 60 | 38 | 2 |
| B-E + 4% WC | 60 | 36 | 4 |
| B-E + 6% WC | 60 | 34 | 6 |
| B-E + 8% WC | 60 | 32 | 8 |

## VI. RESULTS AND DISCUSSION

The different composition like without filler and with filler fiber-reinforced composites specimens was tested in Universal testing machine. From the table, it's clearly revealed that basalt fiber reinforced epoxy composite shows lowest ultimate tensile strength whereas basalt fiber filled with a different weight proportion of tungsten carbide increase with the increase in ultimate tensile strength varies from 208.77 MPa to 278.66 MPa. From fig 2, it concluded that the incorporation of tungsten carbide filler material into the basalt epoxy composites varies from 2% to 6% wt. The proportion of filler material, again it's reduced in the strength with 8% wt. proportion of filler material. The variation of percentage of elongation varies from 2.36% to 3.13 %, from fig 3, percentage of elongation in the material is directly proportional to loading condition, but in 8% wt. of filler shows a higher percentage of elongation and lower strength than 6% wt. of filler filled epoxy composites. This reason for this is voids creation in the filler material during the fabrication process.

**Table- IV: Tensile Test Results for different Proportion of Filler Material**

| Composition | Filler % | % of Elongation (mm) | Peak Load (N) | UTS (MPa) |
|---|---|---|---|---|
| Basalt-Epoxy | 0% | 2.36 | 15657 | 208.77 |
| Basalt-Epoxy + Tungsten Carbide | 2% | 2.63 | 16014 | 213.51 |
| | 4% | 2.87 | 18210 | 242.80 |
| | 6% | 2.97 | 20900 | 278.66 |
| | 8% | 3.13 | 20215 | 269.54 |

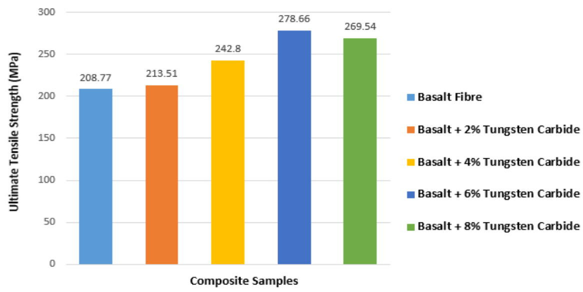


**Fig.2. Ultimate Tensile Strength of Basalt Epoxy Composite**

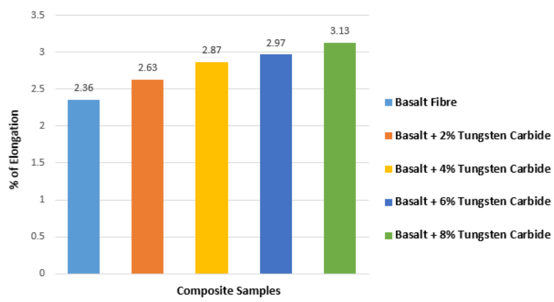


**Fig. 3. % of Elongation of Basalt Epoxy Composites**

## VII. CONCLUSIONS

From the mechanical properties, tensile strength study of tungsten carbide filled basalt epoxy composite and the following conclusions could be drawn:

- The ultimate tensile strength of basalt epoxy without filler is low compared from filler filled basalt epoxy composites, which varies from 208.77 MPa to 278.66Mpa.
- The ultimate tensile strength of basalt epoxy composites increases with the addition of filler materials up to 6% and gradually decreases with increase of filler percentage.
- It shows 33.5% improvement in tensile strength with the addition of filler material.
- The percentages of elongation vary from 2.36% to 3.13%, which clearly shows elongation directly proportional to loading condition.

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