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Tensile mechanical properties of basalt fiber reinforced polymer composite

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ABSTRACT

Basalt fiber-reinforced polymer (BFRP) composites are becoming increasingly popular as a low-cost, ecologically acceptable raw material. FRP composites must resist severe conditions such as chloride ions in coastal marine environments and salt deicing in freezing regions. The resistance of FRPs exposed to the above conditions is important for the safe design and usage of BFRP composites. To utilize BFRP in actual engineering in a reasonable and scientific method it is necessary to understand its mechanical characteristics thoroughly, as described in this work. This paper focuses on the mechanical characteristics of the BFRP sheet. The influences of several parameters on the mechanical properties of BFRP are discussed in detail. The results may provide a reference for manufacturers, further research, and engineering applications.

Keywords: Basalt Fiber, composite fiber, mechanical properties

1.INTRODUCTION

Basalt fibers are produced from basalt rocks, which are the most common type of rock in the crust of the earth. The fibers are processed from molten rock to create continuous basalt fiber, which is then extruded from small nozzles. Compared to other FRP materials, the production process requires less energy and the raw material used in the process is readily available around the world. Basalt fibers do not contain any other additives that make them environmentally safe in the production process. Such elements in the production process give certain cost advantages to basalt fiber over widely used FRP materials. Compared to carbon and aramid fiber, the elastic modulus of basalt fiber is low, which has disadvantages when considering flexural strengthening. However, the ultimate tensile strain is high, which makes it promising to improve seismic efficiency in column retrofitting. Several studies have also shown that basalt fiber is a good replacement for glass fiber in terms of strength, the strain of failure, corrosion, and cost [1], [2]. Compared to glass fiber, basalt fiber has been shown to have better weathering resistance. Carbon, glass, and basalt fiber were tested for 4000 hours under ultraviolet light, which is 20 years under normal conditions. The tensile strength of the fibers was measured where the strength of carbon fiber was only affected by the exposure, but their strength was reduced by the glass and basalt fibers. The reduction in strength of the glass fiber, however, was two times faster than that of the basalt fiber. In the experiment, where the test specimens were heated at 100, 200, 400, 600, and 1200 °C for two hours, good thermal stability was also shown [1]. A comparison of typical material properties can be seen in Table 1 below.

Table 1: Typical dry fiber properties. Properties of carbon, aramid, and glass from [3]. Properties of basalt from the manufacturer (Basaltex).

Fiber	Elastic modulus	Tensile strength	Ultimate tensile strain	Density
	(GPa)	(MPa)	(%)	(g/cm^3)
Carbon				
High strength	230-240	4300-4900	1,9-2,1	1,8
High modulus	294-329	2740-5490	0,7-1,9	1,78-1,81
Ultra-high modulus	540-640	2600-4020	0,4-0,8	1,91-2,12
Aramid	124-130	3200-3600	2,4	1,44
Glass	70-85	2400-3500	3,5-4,7	2,6
Basalt	84	2500	3,15	2,6

2. Fabrication of BFRP plate for tensile test

2.1 Preparation of the Specimens

The BFRP sheets were prepared by the guideline ASTM D 3039/D 3039 M 00 [4]. The specimen manufacturing process comprised two steps: The first step was to cut the BFRP sheet with the size of 250 – 25 - 0.135 mm and 5 number layers. The second step was to impregnate the epoxy resin matrix on a piece of glass board, and a roller was used to remove any trapped air from within the specimens. The specimens were covered by another piece of glass board with something heavy and cured at ambient room temperature for at least 7 days. see fig.1 and fig.2.

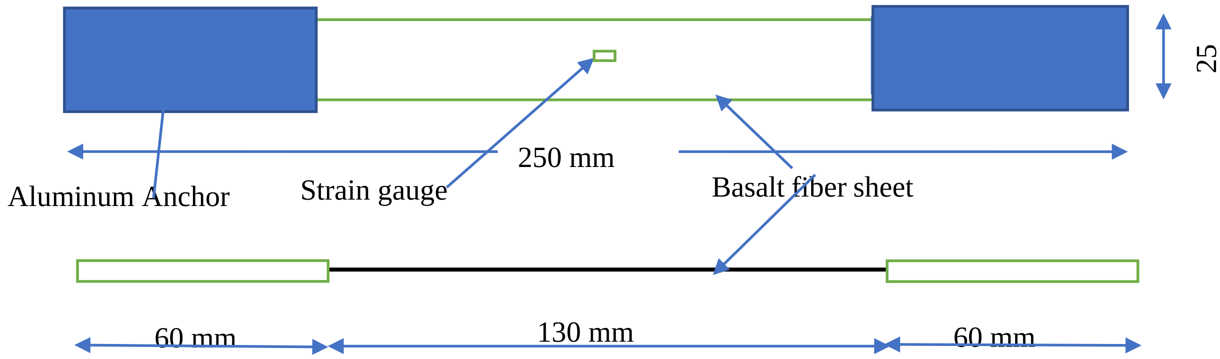

Fig.1. Preparation of the specimen

Fig.2. preparation of the specimen

2.2 Test Procedure

The BFRP specimens were prepared according to ASTM D 3039/D 3039 M-00 [4]. Aluminum sheets were used to anchor at both sides of these specimens, and the specimen details are shown in fig.3. Tensile tests were carried out at a loading rate of 0.08 mm/min. The load was controlled by an electronic universal testing machine in Assiut University laboratory equipped with a 100 KN load cell shown in fig 4. The longitudinal strain of BFRP sheets was measured to determine the elastic modulus.

Fig.3 the specimen test

Fig.4. an electronic universal testing machine

2.3 Tensile Coupon Test Specimens

The difference in thickness is generally observed in tested tensile specimens because of variance in the amount of epoxy resin used in a hand layup method which also occurs in the retrofit process of structural components. Therefore, the thickness used in calculations is the nominal thickness of the dry fabric sheet. The BFRP material tensile strength is then calculated by:

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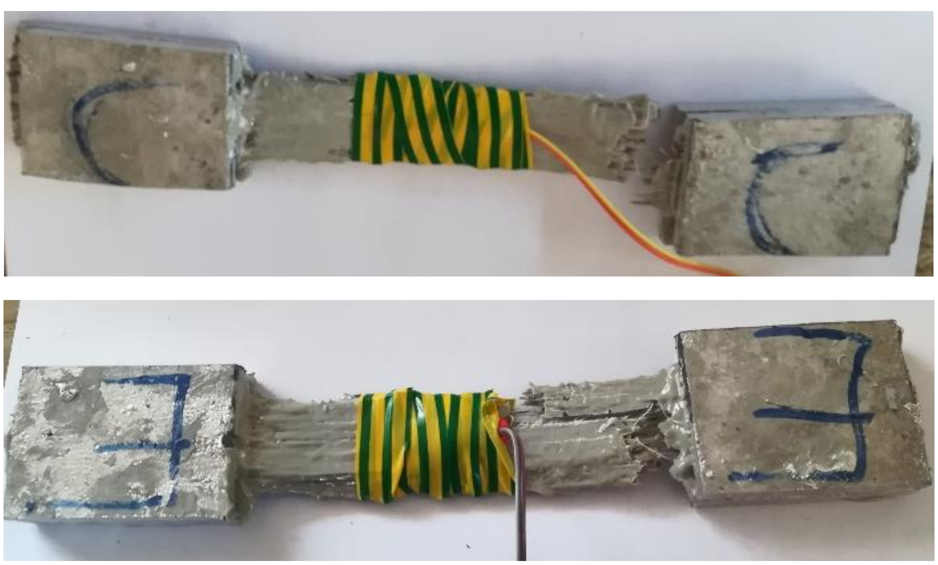
$$F_f = \frac{F_t}{n\, w\, t_f} \qquad (1\text{-}1)$$

where F_t is the ultimate tensile force from the test, w is the average width of the specimen, t_f *is* the nominal thickness of the dry fabric sheet and n is the number of layers in the specimen. The elastic modulus is estimated according to the ASTM standard where the elastic modulus is calculated within a given strain range from a stress-strain curve. The elastic modulus is given by:

$$E_f = \frac{F_f}{\varepsilon_f} \qquad (1\text{-}2)$$

2.4 Test Results BFRP plate for tensile test

All specimens showed a good linear response up to the first failure at peak load. At that point, the applied stress decreases as the fibers at the edge rupture and the stress start increasing again until the whole section ruptures see fig.5. The rupture of the fibers occurred generally from the end of the active gage length of the specimen. The fact that the fibers at the edge rupture first indicates that the orientation of the fibers to the applied tensile load is not perfectly parallel, which however can be the case in structural strengthening. Therefore, the ultimate strength and strain are taken at the peak where the first failure occurs. This is considered to represent the material strength of the BFRP jacket. The results of tensile tests on tensile test specimens are shown in Table 1. Tensile stress versus longitudinal strain of tensile coupon test specimens sees in Fig 6.



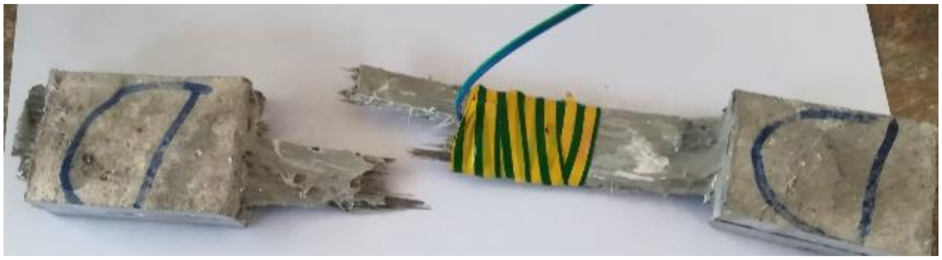


Fig.5. Tensile Coupon Test Specimens

Table Error! No text of specified style in document.**.1 Results of tensile tests on tensile test specimens.**

Sample	No. of layers	Thickness of sample	Length of sample	Ultimate Load	Ultimate Stress	Ultimate strain	Young's Modulus
		(mm)	(mm)	(N)	(MPa)	%	(MPa)
A	5	0.135	25	10200	604.44	1.22	48745.52
B	5	0.135	25	10300	610.37	1.34	45550.03
C	5	0.135	25	10800	640.00	1.5	42666.67
D	5	0.135	25	10400	616.30	1.38	44659.15
E	5	0.135	25	10000	592.59	1.11	49382.72
Average					612.741	1.3	46200.816

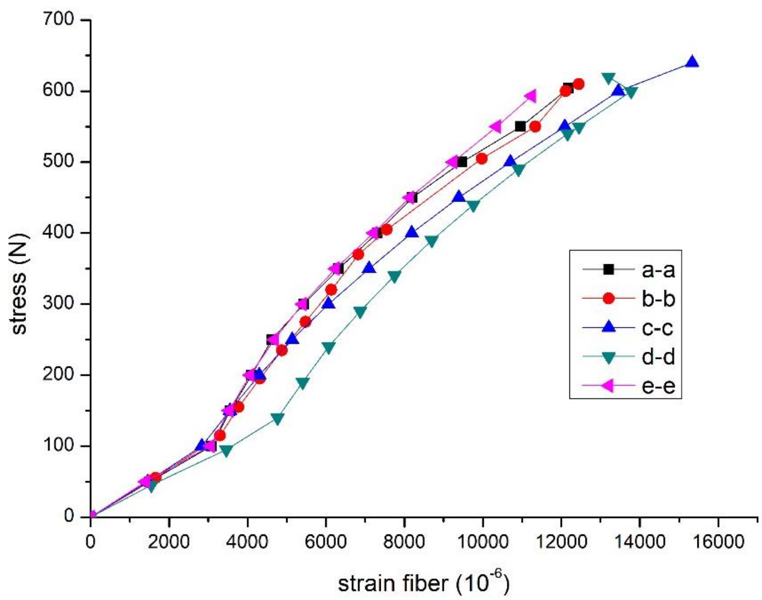


Fig.6. Tensile stress versus longitudinal strain of tensile coupon test specimens

3. Conclusions

This paper briefly introduces the experimental results of the basic mechanical performance of basalt fiber reinforced plastics (BFRP) and analyzes the possible factors influencing basic performances. The research results can be referenced for manufacturers. There are some reference values for further researching continuous basalt fibers. It is good for the application and dissemination of basalt fiber in civil engineering.

4. REFERENCES

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