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Properties of Composites with Geopolymer Matrix Reinforced by Basalt Fabric

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Abstract. The mechanical properties of composites made of basalt fabric reinforcement and geopolymer matrix have been investigated. Two different types of geopolymer matrix were investigated and two types of basalt fabric were used - namely weave and twill. The tensile and flexural properties of composite samples were investigated both without any thermal treatment and after heating to 500 ° C followed by slow cooling to room temperature. Tensile strength of basalt fabric alone was also investigated before and after the thermal treatment. The mechanical properties of composite and fabric have deteriorated as a result of heating but samples retained their integrity and partly also the strength. The basalt fibers and fabrics can be regarded as a good strengthening material for geopolymer composites used for fire resistant or temperature resistant panels.

Introduction

Geopolymers are a class of amorphous aluminosilicate materials composed of cross-linked alumina (AlO_4) and silica (SiO_2) tetrahedra to form polysialates, with an alkali metal ion to balance the negative charge [1]. Geopolymers have shown potential as a low-cost, environmentally friendly structural material with the ability to maintain strength at elevated temperatures. Geopolymers can be used as a binder system for a broad variety of reinforcement materials. This property guarantees maximum load transfer from the geopolymer matrix to any reinforcement phase.

Basalt fibers can be considered environmentally friendly. Basalt is the most common reinforcing phase of the geopolymer that significantly improves the mechanical properties and high-temperature stability of composites. Young’s modulus of basalt fiber varies between 78 and 90 GPa [2,3]. Compared to glass, basalt fiber has higher or comparable elastic modulus and tensile strength and higher chemical and thermal stability, as well as good thermal, electrical, and sound insulating properties.

The thermal insulating ability of basalt is three times that of asbestos, and due to such good insulating properties basalt is used in fire protection [4,5]. Basalt has electrically insulating properties which are 10 times better than glass. Basalt has much better chemical resistance than that of glass fiber, especially in the presence of strong alkalis [5,6,7].

Thermal stability of basalt fibers was investigated and reported in several papers. The strength of the basalt fibers after thermal treatment depends not only on the heating temperature but also on the time how long the fibers are exposed to high temperature. The comparison of the results of measurements [5,7,8] in Fig. 1 shows even the improvement of strength in the range of lower temperature but the results vary widely after heating to higher temperatures. The main factor determining the heat temperature stability of basalt fibers is their crystallization behaviour which depends on the chemical composition of basalt fiber [3].

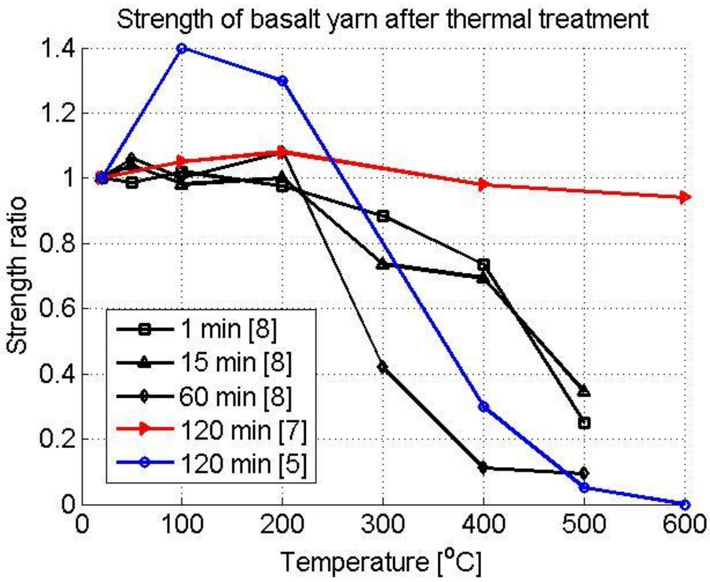

Fig. 1. Strength ratio of basalt yarns after thermal treatment.

The behaviour of the basalt fibres in geopolymer matrix during the heat treatment is quite different from the fibres alone due to chemical interaction [10]. The strength of the composite decreases as the result of increasing crystallisation and melting of the fibre occurred at higher temperatures. This process results in an increasingly brittle failure of the fiber and the composite. However, other studies [11,12] show that the use of basalt fibres as the reinforcement of geopolymers is justified for applications up to 600 °C.

Experimental procedure

Two geopolymer resins with the working name B3P1 and FC4 were furnished by UniCRE Czech Republic. Geopolymer matrix FC4 consists of potassium water glass, potassium hydroxid (KOH), silica fume, metakaolinite and boric acid. Geopolymer matrix B3P1 consists of potassium water glass, metakaolinite and calcium. Composite panels 250x250 mm were prepared using the hand lay-up of six layers 0°/90° of 2-D plain weave basalt fabrics of weight 400 g/m2 furnished by Basaltex CZ. The chemical composition of the basalt fibers used in our composites is in Table 1.

Table 1. Chemical analysis of basalt fibers by spectrometer RX Bruker [9]

Oxid	SiO_2	Al_2O_3	CaO	MgO	TiO_2	Na_2O	K_2O	Fe_2O_3	MnO	SrO	ZrO_2	ZnO
% m	54.39	17.6	8.92	3.62	1.12	2.66	1.66	9.77	0.14	0.4	0.04	0.02

The plates then were covered by separation and suction cloths. The process was followed by vacuuming in order to improve the infiltration of the matrix into the reinforcing fabric. Panels then were left in a compression press at ambient temperature for 4 weeks. The thickness of panels were about 2 mm. Samples of width 20 mm and length 200 mm were prepared from the cured panels by laser cutting. Tensile tests were performed at Instron 5967 with a video-extensometer and three point flexural tests were performed at TIRA 2850 testing machine.

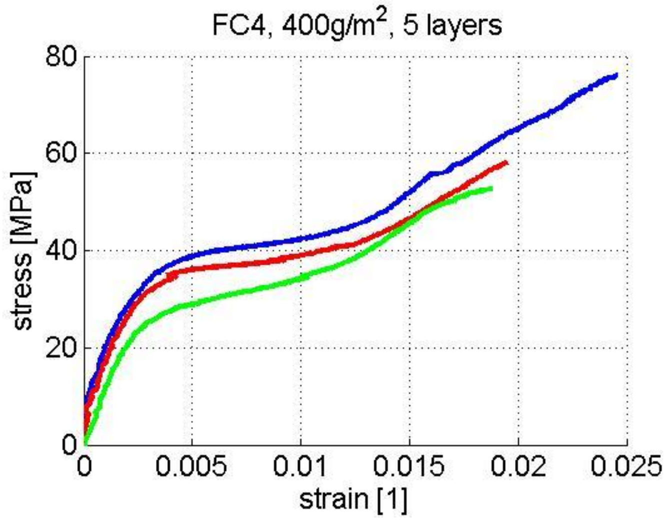

Fig. 2. Matrix FC4 with 5 layers of weave basalt fabric no heat treatment.

The strength in tension and in three point bending was measured after 30 min exposure to elevated temperature 500^{o}C.The results of the tensile test of composite with FC4 matrix without the heat treatment are in the graphs in Fig.2. Both types of composite had the same strength without the heat treatment. Samples with B3P1 matrix maintained integrity at elevated temperatures but the strength decreased three times as can be seen in Fig. 3. The samples with FC4 matrix became brittle after the thermal treatment and the strength was unmeasurable. The results of three point bending are in Figs 4 - 6.

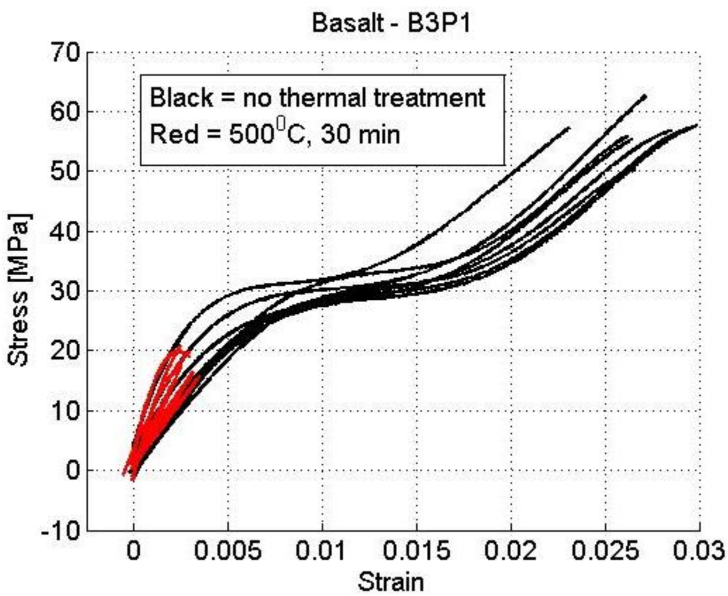

Fig. 3. Matrix B3P1 with 9 layers of twill basalt fabric.

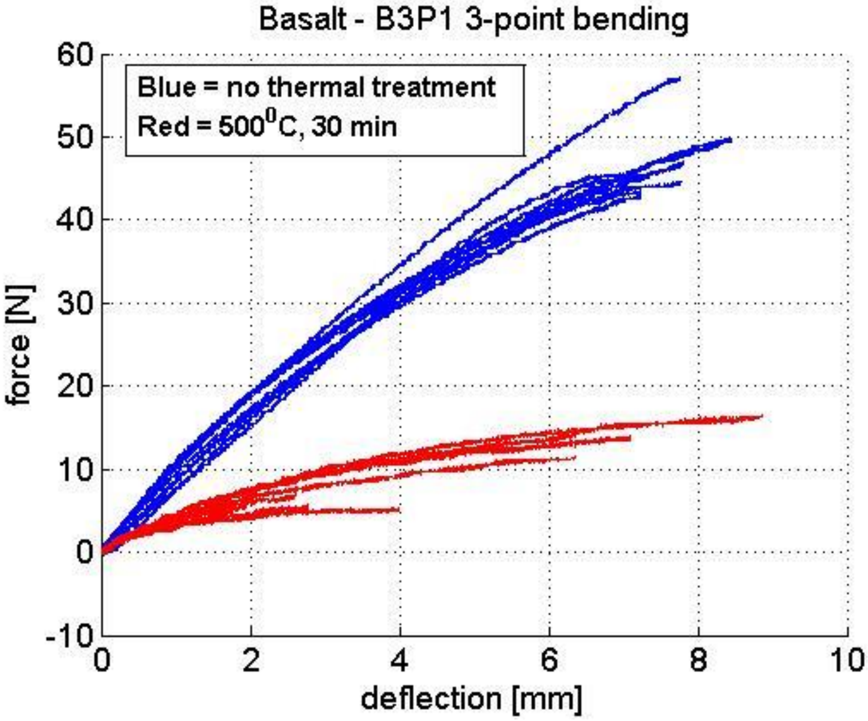

Fig. 4. Three point bending of the composite specimens with B3P1 matrix reinforced by 9 layers of twill basalt fabric.

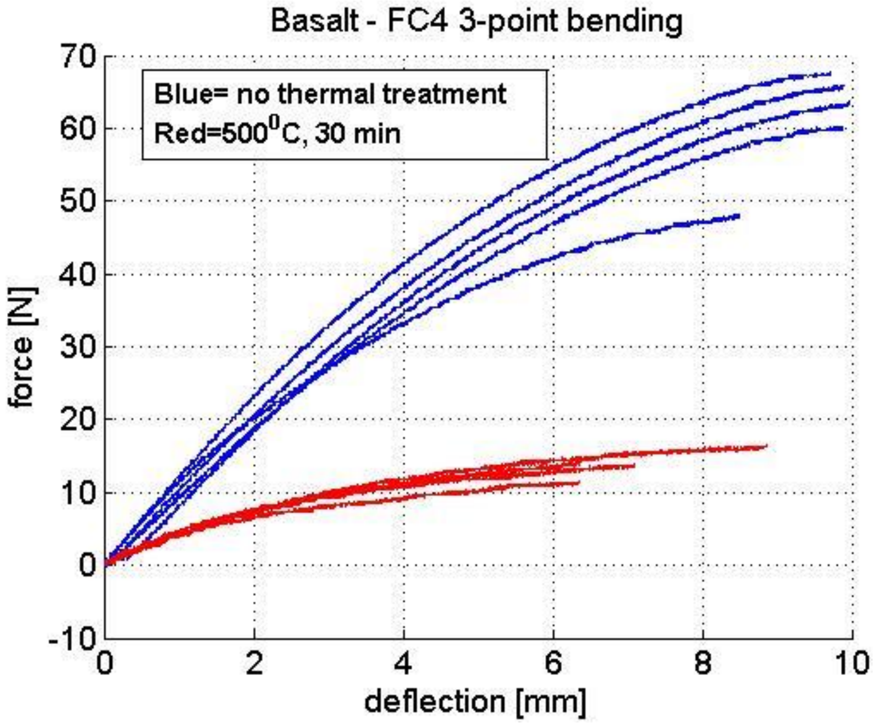

Fig. 5. Three point bending of the composite specimens with FC4 matrix reinforced by 9 layers of twill basalt fabric.

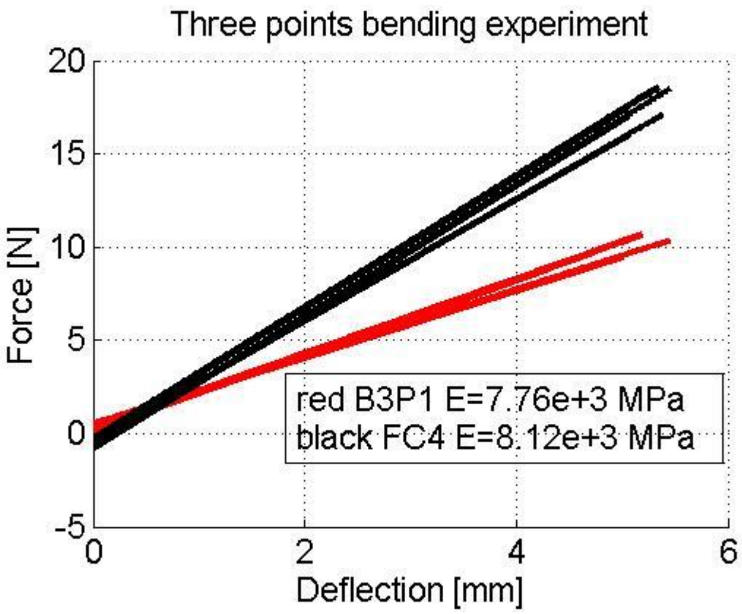

Fig. 6. Flexural modulus in three point bending of the composite specimens with reinforced by 5 layers of weave basalt fabric.

Conclusion

Thin composite panels were produced by hand lay-up followed by vacuuming to achieve the good penetration of geopolymer matrix within basalt fabric yarns. This process provided uniform mechanical properties throughout the entire panel. Tensile strength and three-point flexural strengths values were determined at ambient temperature for two groups of samples with different geopolymer matrix. Other specimens were exposed to elevated temperature at 500^{o}C for 30 minutes in an oven without forced air circulation. The samples were subjected to the same tests. Both types of composite without thermal treatment had approximately the same strength values. The strength of samples dropped to approximately one third after the heat treatment but the material did not lose its cohesion. These properties can be further improved by a suitable composition of a geopolymer matrix which should not attack basalt fibers chemically. This problem is the subject of our further research.

Basalt fiber reinforced geopolymer composites are non-combustible materials which can be used for different applications where fire endurance and non-combustibility together with structural strength are required. Basalt reinforced geopolymer composites could be used in different industrial applications at elevated temperatures between 300°C-900°C. The composites are also suitable as panels in fire curtains or barriers inside buildings.

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