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Effects of Basalt Fibers on the Mechanical Properties of Fire Resistant Composites

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Abstract. Article presents the results of an experimental program aimed at investigating of the mechanical properties of composites based on aluminous cement with the addition of basalt fibres, which could be used in the manufacture of components resistant to high temperatures, including the retention of mechanical properties. Silica composites based on Portland cement and silica aggregates are not able to resist the effects of high-temperatures [1], therefore a heat-resistant mixtures in this experiment includes only components that are able to resist the effects of high-temperatures**.**

Introduction

Industry of composite materials is a constantly growing area of development. Due to the increasing demand for new building materials is essential to actively devote the development of composite materials.

Composites are very advantageous, because they are essentially produced for the needs of the final application, and not only by its structure and properties, but also by the production technology. When designing various combinations of materials to be used for the production of composites, it is necessary to take into account not only the correct selection of materials, but also their correct mixing ratio [2].

Materials and Methods

To create a heat resistance composite was in the experiment used aluminous cement Secar®71 in combination with crushed basalt aggregate of fraction 0/4 mm and 2/5 mm. According to documents available from the manufacturer [3] it is possible to use this cement at temperatures up to 1 700 °C. The primary purpose of this work is to determine the degree of influence of the basalt fibre ingredients on the final mechanical properties of the heat resistance composite. These properties were investigated on a series of samples (with dimensions of 40×40×160 mm) dried at 105 °C or a series loaded for 180 minutes with high temperature of 600 °C, or 1 000 °C. For the purpose of the experimental program were designed six mixtures, whose compositions are provided in Table 1.

Table 1. Composition of mixtures.

Mixtures	Components [kg/m^3]						
	Plasticizer	Water	Aluminous cement	Basalt aggregates		Basalt fibres	
				0/4 mm	2/5 mm	6.35 mm	12.7 mm
AC_BF 0.0	22.75	224	900	880	220	0	0
AC_BF 0.25						0.73	6.52
AC_BF 0.5						1.45	13.05
AC_BF 1.0						2.9	26.1
AC_BF 2.0						5.8	52.2
AC_BF 4.0						11.6	104.4

In proposed mixtures was used a combination of fibres with diameter of 13 μm and with lengths of 6.35 and 12.7 mm. The density of the basalt fibres is 2 900 kg/m^3 and the tensile strength 2 000 MPa [4].

In present times, the basalt fibres are successfully replacing glass and carbon fibres. The cause is comparable physical, thermal and chemical properties of basalt fibres, which are compared to carbon fibres several times cheaper [5]. Another important advantage, which is the primary requirement of the experiment, is the heat temperature resistance of basalt fibres. These fibres have a temperature range of application about -200 to 800 °C [4].

Basalt material, from which the fibres are manufactured, is in terms of health harmless, is chemically stable and is intended for technical use. Basalt fibres are not fibrogenic and carcinogenic [4].

Measurement and Results

For each proposed mixture of composite material was made out nine test samples. Due to the higher hydration heat the fresh samples of composites were stored in an environment with a relative humidity of 100 % and a temperature of 20 ± 3 °C for 28 days. The evaporation from the surface of fresh sample was prevented with airtight foil. After 28 days the samples were dried at temperature 105 °C for 24 hours, in order to avoid creating of defects caused by the escape of vapour during subsequent thermal loading.

When the drying was completed, the samples were taken to high-thermal loading. Dried samples were divided into three groups of three samples. The first group was tested without undergoing the high-thermal loading; the other two were submitted to high-temperatures of 600 and 1 000 °C. The burning of samples was carried out in an electric kiln, which automatically increased the temperature by 10 °C/min from ambient temperature to the desired values of 600 or 1 000 °C. The set temperature was then maintained automatically at the desired value for 180 minutes and then the kiln cooled naturally.

After high-thermal loading was investigated flexural strength of the samples and on the remaining fragments was tested compressive strength. In Table 2 are stated the values of flexural and compressive strength from all mixtures. Table also creates an overview of the dependence of bulk density on temperature. Values in table were determined from the average of three samples, or six in the case of compressive strength.

Table 2. Properties of composites.

Mixtures	Bulk density [kg/m^3]				Flexural strength [MPa]			Compressive strength [MPa]		
	20 ± 3 °C	105 °C	600 °C	1000 °C	105 °C	600 °C	1000 °C	105 °C	600 °C	1000 °C
AC_BF 0.0	2395	2335	2257	2184	5.2	2.1	1.5	47.7	31.1	18.8
AC_BF 0.25	2373	2308	2095	2050	16	7.8	3.4	113.5	68.3	27.1
AC_BF 0.5	2504	2466	2317	2267	11.9	5.9	3.7	100.5	64.1	36.2
AC_BF 1.0	2441	2370	2236	2175	13.4	6.2	3.7	93.9	52.7	26.4
AC_BF 2.0	2424	2361	2225	2210	12.3	6.6	3.8	94.1	58.6	29.8
AC_BF 4.0	2267	2197	2071	1966	18	9.8	3.9	99.1	58.8	21.2

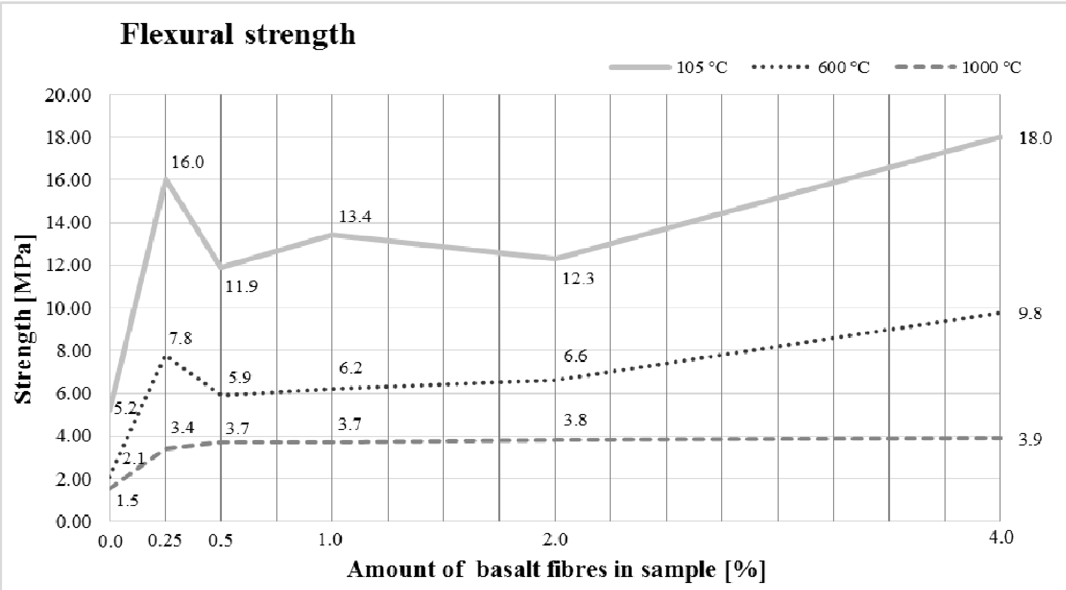

Fig. 1. Flexural strength of tested samples.

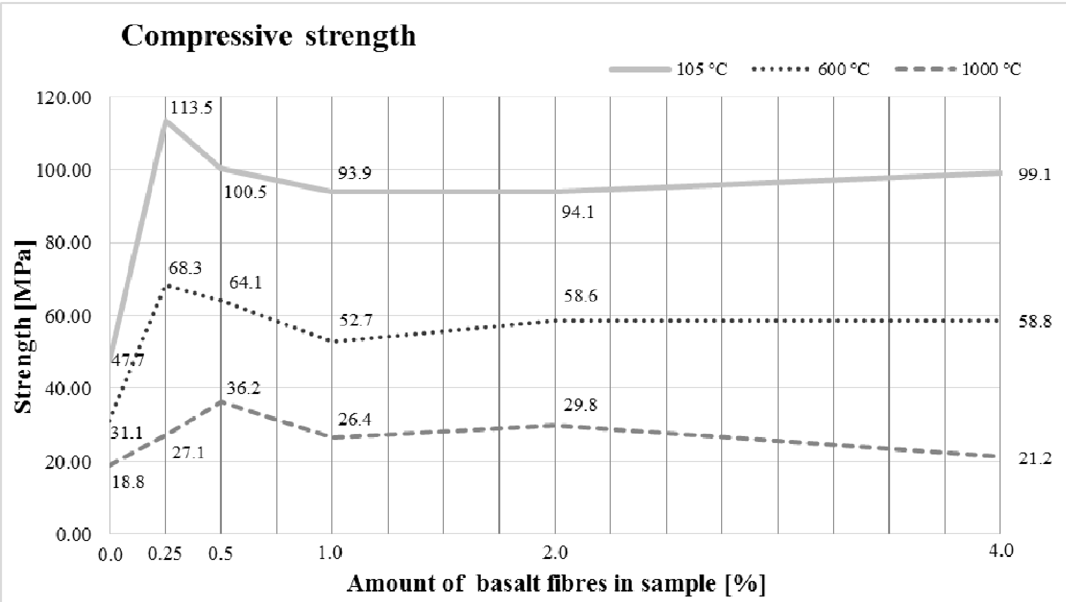

Fig. 2. Compressive strength of tested samples.

Conclusions

This work presents the results of laboratory measurements of composite specimens exposed to high temperature stress as compared to the test specimens, which were not exposed to these stresses.

The proposed mixtures in the experimental program are mutually different in amounts of basalt fibres. As you can see in the Fig. 1 and Fig. 2, the presence of basalt fibres in the composite samples worked on final mechanical properties favourably. By increasing the dose of fibres there was the expected increase in the values of flexural strength and compressive strength of composite materials.

The noticeable strength values occurred in samples with 0.25 % of the fibres from 1 m^3 of mixture. Significant values of mechanical properties also reached mixture with 4.0 % of basalt fibres. This amount of fibres in the mixture, however, did not satisfy the requirements for workability.

Suitable combinations of basalt fibres with the other ingredients mentioned in the experiment leads to the formation of heat resistant composite material with satisfactory workability of the fresh mixture. The mechanical properties of the material are designed to a very high level, as well as its other utility properties. The negative effects such as explosive popping do not show even when the temperature increase to the 1000 °C.

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References

[1] E. Vejmelková, R. Černý, Thermal Properties of PVA-Fiber Reinforced Cement Composites at High Temperatures, in: H.W. Liu (H.W. Liu (Ed.), Material and Environmental Science, Building Engineering, Biomedical and Bioinformatics Technologies, Trans Tech Publications, Uetikon-Zurich, 2013, pp. 45-49.

[2] M. Keppert, E. Vejmelková, R. Černý, S. Švarcová, P. Bezdička, Microstructural changes and residual properties of fiber reinforced cement composites exposed to elevated temperatures, Cement Wapno Beton 17/79 (2012) 77-89.

[3] Information on http://www.secar.net/-Brochures

[4] Information on http://www.basaltex.cz/cedic/cedic_charakteristika_cz.htm

[5] C. Colombo, L. Vergani, M. Burman, Static and fatique characterisation of new basalt fibre reinforced composites, in: Composite Structures 94 (2012) 1165-1174.