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Interaction of Composite Reinforcement Produced from Rovings with High Performance Concrete

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Abstract. The reinforcement of concrete with composite technical textile creates a tensile load-bearing capacity. It allows the elimination of steel reinforcement and minimisation of concrete cover. Then the concrete cover is designed with respect to the cohesion of reinforcement with concrete. With textile reinforcement very thin structures could be realized. The aim of this paper was to determine the interaction conditions of carbon and basalt composite reinforcement in a matrix of epoxy resin with high performance concrete (HPC). The tensile strength of used composite reinforcement and the other mechanical parameters of HPC were determined by experimental tests. Experiments copied the production method of technical textiles. The two material combinations present the influence on the design of the structures with textile reinforcements.

Introduction

Reinforced concrete is currently the most widely used material in civil engineering. It utilizes combination of a high tensile strength of the steel and a high compressive strength of the concrete. To design very thin-structured concrete elements it is possible to efficiently use the different kinds of new materials with higher performance quality. For example, textile reinforced concrete (TRC), which uses the multi-axial technical textile in combination with HPC [1].

Technical textiles are made of alkali resistant (AR) glass, carbon, basalt, aramid and their mutual combinations. Technical textiles use to be placed in the main stress direction. It leads to the maximal effectiveness of used material in comparison to the fibre reinforced concrete (FRC). In the last few years, there was observed magnificent development of TRC, however the development of standards regarding this new material is definitely not so fast. Consequently there is a shortage of detail and particulars information regarding technical parameters of new materials and entire TRC structures [1,2]. One of the most important parameter needed for structural design is the cohesion – the interaction conditions of composite textile reinforcement and HPC.

Experimental Investigation

The aim of particular experiment performed within wider research focused to TRC application in building envelopes was to create samples of composite reinforcement, design the test procedure of interaction between composite reinforcement and HPC (pullout test) and determine the cohesion. The other parameters of composite reinforcement and HPC were determined by experimental tests, too.

Materials. Composite textile reinforcement is made from the infinitely long fiber bundles (rovings) and a matrix of the epoxy resin. Basalt and carbon roving have been used for this experiment. We have used a larger quantity of epoxy resin of low viscosity (60 – 70 % in the cross-sectional area) to reach a better interaction between fibers.

The composite reinforcement has been applied to the sample of HPC. Concrete has been used without any reinforcing fibers, with a maximum grain size 1.2 mm. Concrete compressive strength was 106 MPa on samples of cubes with an edge length of 100 mm and it was 143 MPa on broken samples of prisms 40 x 40 x 160 mm. Tensile strength of concrete in bending was 15.6 MPa on samples of prisms 40 x 40 x 160 mm. Static modulus of elasticity of concrete in compression was 49.5 GPa on samples of prisms 100 x 100 x 400 mm. The mixture is presented in Table 1. This mixture of HPC was developed and optimized at the Czech Technical University (CTU) in Prague [3].

Table 1. HPC mix design and material properties.

Mix content	kg/m^3
Cement I 42.5R	680
Technical silica sand	960
Silica flour (ground quartz)	325
Silica fume (microsilica)	175
Superplasticizers	29
Water	171
Total	2 340

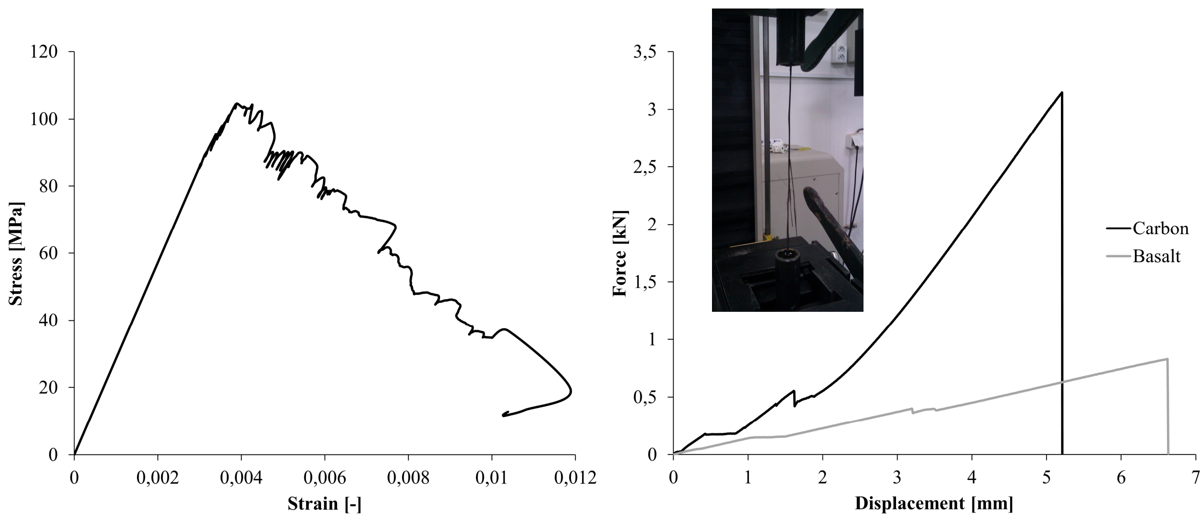


Fig. 1. Stress-strain curve from lab tests of concrete in compression (a) and tensile traction-displacement curve of basalt and carbon composite reinforcement in tension (b).

Testing of Interaction. Test procedure has been done according to the standard CSN 73 1328 [4] for testing of steel reinforcement and standard ACI 440.3R-03 [5] for testing of composite reinforcement. Samples dimensions have been adapted to possibilities of the laboratory equipment. Steel sleeve has been installed on one side of the composite reinforcement. Steel sleeve allowed fixing sample to the testing rig (Fig. 2).

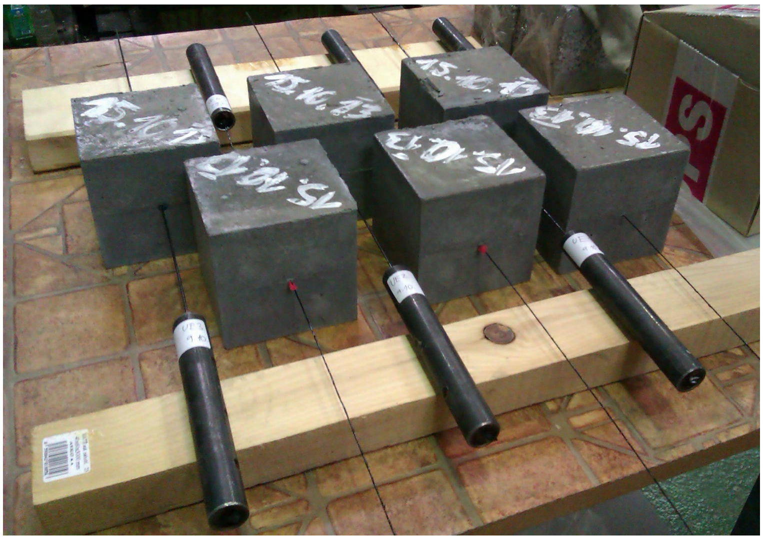


Fig. 2. Completed specimens.

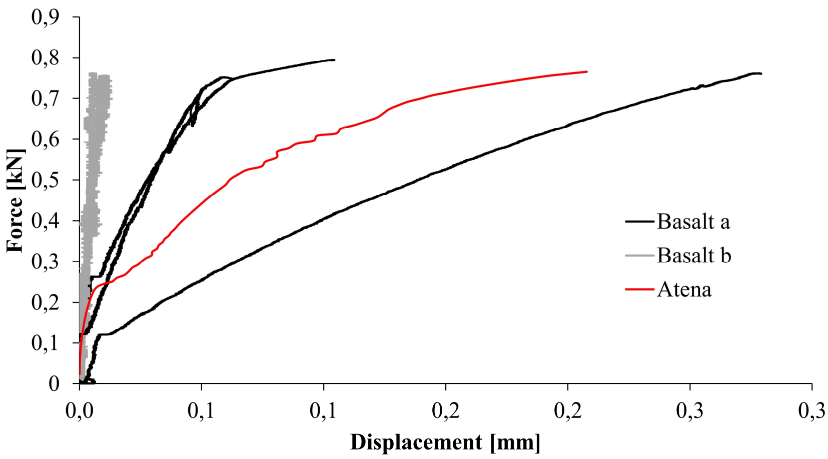
Results

Mechanical parameters of composite reinforcement which were used during the experiment and calculated value of cohesion are presented in the Table 2 below.

Table 2. Mechanical parameters of composite reinforcement and value of cohesion with HPC.

	d [mm]	A [mm^2]	F_{max} [N]	f_t [MPa]	E [MPa]	τ_m [MPa]
Basalt	1,02	0,82	780,7	951	19500	2,20
Carbon	1,90	2,85	3041	1066	45000	1,42

These particular values measured in the experiment were supplemented by values from the numerical model. The numerical model was created by using program for non-linear analysis of reinforced concrete and concrete structures called Atena 2D. Results from experiment and numerical model are presented in the Fig. 3 and Fig. 4. Specimens *a* have a 40 mm of reinforcement in contact with concrete, specimens *b* have a 60 mm of reinforcement in contact with concrete. This is the reason of differences of curves. Numerical model was created only for contact length 40 mm in the case of basalt reinforcement and 60 mm in the case of carbon reinforcement.



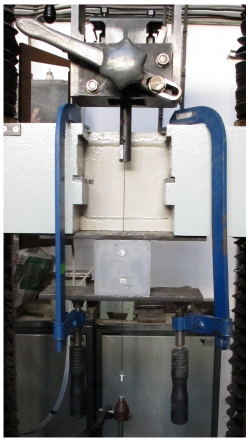


Fig. 3. Pull out test, force vs displacement curves of basalt composite reinforcement.

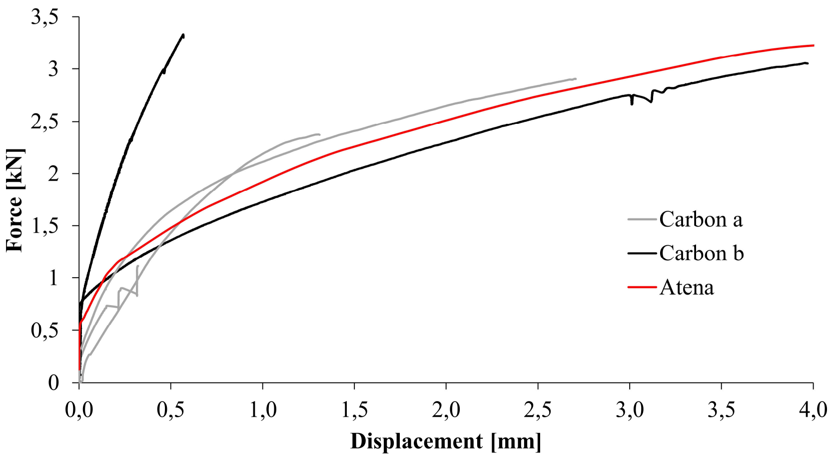


Fig. 4. Pull out test, force vs displacement curves of carbon composite reinforcement.

Conclusions

Composite reinforcement started to slip too soon in these specific concrete samples. On the other hand results showed that this non-steel reinforcement has a big ductility. One possible solution could be to modify the surface properties of the composite reinforcement, e.g. by using silica sand. Results of performed experiment can be used as a basis for designing of structures from HPC reinforced by technical textiles in matrix of epoxy resin. Results also can be used as a basis for further research in the field of TRC and individual fiber bundles. However results cannot be used as a basis for directly concreted technical textiles without matrix from epoxy resin.

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