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Heat Effect on Tensile Properties of Textile Reinforced Concrete

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Abstract. Experimental tests of tensile properties of textile reinforced concrete have been performed in this paper. Textile reinforced concrete (TRC) is used currently for the production of thin-walled structures, which life- and service-time are significantly affected by the presence of crack induced by the action of the environment. TRC is relatively new composite material based on textile reinforcement and high performance matrix. The most of research works was focused on the description of failure mechanism, mechanical and durability properties of used materials, however the influence of increased temperatures has not been thoroughly studied yet. Increased temperatures could occur on the surface of real structures. Dog-bone shaped specimens were heated to 40, 60 and 80°C and consequently tested in direct tension tests. Glass textile fabric have been used as a reinforcement of high performance concrete matrix. No visual defect was apparent on specimens and the concrete matrix properties decreased more significantly than properties of textile reinforcement.

Introduction

This article describes tension behavior of glass textile reinforced concrete under elevated temperature conditions. Textile concrete starts to be a popular composite material for new constructions [1,2]. Every new material needs to be tested in various extreme conditions such as acidic environment, freeze-thaw or high temperature. There have been performed several tests on the same shape of specimen with more types of reinforcement (number of layers, type of reinforcements) which showed important contribution of reinforcement mostly in after-crack part of loading [3,4,5].

Kodur in his work [6] mentions that there is not enough knowledge about effect of high temperatures on new types of concrete (such as self-consolidated concrete or fly ash concrete) comparing to normal or high strength concrete. Tested properties do not depend only on the temperature, but also on the heating rate or temperature gradient. Thorough research dealing with textile concrete was conducted by Chira et al. [3]. This work was focused on the on the cohesion of various textiles with cement based matrix. Number of experimental works was focused on the mechanical properties and properties related to the durability of TRC [4,5]. However, the knowledge of behavior under elevated temperatures induced by the sunshine is still missing.

The main aim of performed work was to document behavior of TRC concrete in elevated temperatures, which could be induced by the natural action of the environment. Any significant changes in the properties of cement based matrix are not expected, however decay of tensile strength of used TR could be crucial safe parameter. Test specimens in this work were heated on 40, 60 and 80 degrees of Celsius and tested in direct tension. Concrete mixture had properties of high strength concrete with compressive strength after 28 days 100 MPa.

Test specimens were in a shape of a “dog-bone” with a thickness of 30 mm and were loaded with loading speed 0.5 mm/min.

Experimental methods

There does not exist any code or guideline to direct tension textile reinforcement concrete testing. Direct tension tests were executed on dog-bone shaped specimens at a machine with specially shaped claws mounted on joints to the machine. This shape has been used in more previous experiments executed by authors, which gives them many data [4,7,8]. However, TRC plates could be used as well [9]. The quality of used cement based matrix was controlled in terms of flexural strength and compressive strength. The composition of used matrix followed previous research of Holcapek et al. [8]. All specimens were tested after 28 days after the production and they were cured in laboratory conditions. Next step was their conditioning in furnace to heat them on required temperature for 24 hours. Each specimen was tested immediately after its extraction from the furnace to prevent cooling down.

Direct tension tests were carried out on a MTS QTest 100 machine with special-shaped claws with installed joints at both ends to provide direct tension without bending. Loading speed was set to 0.5 mm/min and time, elongation and loading strength were recorded. Except of tensile tests, compressive strength and flexural strength was investigated at prismatic specimens 40x40x160 mm^3 according to CSN EN 1015-11 [10]. Emphasis was placed on several points in a stress diagram, namely the stress at the activation of textile reinforcement after first crack occur, maximum force at un-cracked specimen and maximum force bored by reinforcement. All values are possible to read from strength – elongation diagram.

Materials

Cementitious matrix. Composition of used matrix is shown in Tab. 1**Chyba! Nenalezen zdroj odkazů.**. Basically, it´s composition equals to high strength concrete, where the stress strength after 28 days exceeds 100 MPa [8]. These modern composites exhibited high density and durability. High resistance of commonly used HPC matrix in determined by the utilization of relatively high volume of silica fume, which reduces the content of Portlandite and simultaneously transform that on the non-soluble C-S-H phases (CaO-SiO_2-H_2O) contributing to the mechanical performance in case of cement based matrix. The development of HPC matrixes is also closely related to the application of advanced chemical admixtures, which considerably modify rheology of fresh composite and allow good workability. This matrix is suitable for TRC mostly because of the fine structure, the biggest grain is 1.2 mm and it very easily enter “eyes” in textile reinforcement.

Tab. 1 Composition of used matrix

Component	Weight ratio [-]
Cement CEM I 42.5 R	1
Silica fume	0.19
Silica sand 0.1/0.6	0.48
Silica sand 0.3/0.8	0.5
Silica sand 0.6/1.2	0.38
Silica powder	0.48
Superplasticizer	0.011
Water	0.35

Textile reinforcement. Textile reinforced concrete is relatively new composite material. In this case, E-glass textile reinforcement with styrene-butadiene coating was used in combination with high-strength concrete matrix. Glass textile reinforcement is usually used in façade systems to prevent cracks, but recently started to be used in concrete technology thanks to its easy manipulation, low price, good mechanical properties and no need of covering layer. Textile reinforcement can be made from different materials (carbon, glass, plastics, etc.), where each of them has positive and negative sides. There also exists alkali resistant glass, which does not need any surface treatment, but the price is higher. Reinforcement designated “R 585 A101” produced by Adfords Ltd. Was used in the experimental program. This code means: R – textile fabric; 585 is square weight - 585 g/m^2, which is often designated as “tex”; A101 is the code for used surface treatment, what means alkali-resistant coating on basis of styrene-butadiene. Its textile grid has dimensions 4.5 × 5.5 mm^2, what ensure suitable compaction of casted matrix and also homogeneity of produced samples.

Results

Flexural strength and compressive strength were tested on non-heated prisms to document actual properties of used matrix. Flexural strength resulted to be 10.5 MPa and compressive strength equals to 106.1 MPa. These results confirmed previous research. Even its high mechanical properties, this material is not suitable for structures because of its brittle failure mode. That is why, it is necessary to apply some kind of reinforcement.

Direct tension strength tests conducted on dog-bone specimens showed important decrease of concrete tension strength - measured as a force needed for first crack, especially for the highest applied temperature. Average value for reference samples was 5344 N, for samples heated to 40 °C the value dropped to 1629 N (30.5 %), at 60 °C to 2542 N (47.6 %) and 2998 N (56.1 %) for 80 °C heated samples. These findings is likely surprising, because such “low” temperatures are commonly used for various laboratory procedures. Otherwise, very low amount of hydrates decompose in this temperature interval.

However glass textile reinforcement did not suffer major property change, but the overall trend of strength was decreasing. Important role in this case might have the styrene-butadiene coating of glass, which is a border between glass and concrete matrix. First important value was the strength when crack in concrete matrix occurred. Average maximal strength obtained in textile reinforcement after first crack occur dropped from 1907 N (reference samples) to 1380 N (40 °C, 72.4 %), 1221 (60 °C, 64 %) and 1226 N (80 °C, 64.3%). It is obvious that the major decay take place after the exposure to 40°C, additional increasing of the temperature did not affect residual force/stress in the reinforcement.

Last important value is force/stress, when textile reinforcement was fully activated. At reference samples, the value is 1318 N and with higher temperature, the lower the strength value was, specifically 1270 N (40°C, 96.4 %), 1242 N (60°C, 94.3 %) and 830 N (80°C, 63 %). These results are well documented on the Fig. 1. It is well visible that this crucial moment in the failure of TRC composite is not significantly affected by the temperature. Nevertheless, after 80°C there is obvious loss of mechanical performance, but this value of surface temperature in relatively improbable in normal conditions.

Shape of a load – displacement curve is similar to reference samples, maximum strength values for each part varies. Heat affects the whole volume which causes changes on reinforcement. Deeper investigation with more samples and wider variety of tested temperatures is necessary for further research. No visual changes were apparent on all heated specimens.

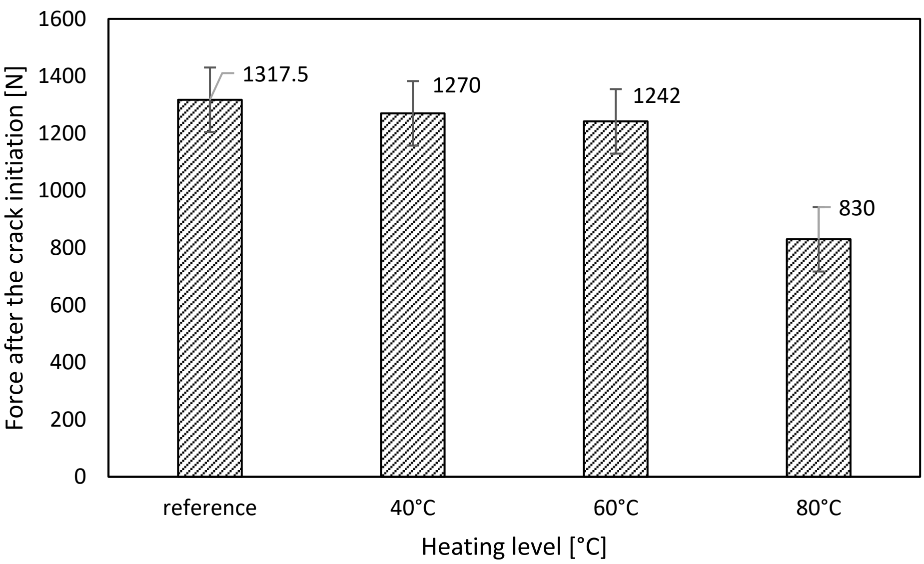

Fig. 1 Force in textile reinforcement after the crack initiation

Conclusion

Aim of this work was to experimentally assess influence of elevated temperatures to tension properties of composites with glass textile reinforcement. Studied conditions could appear in real conditions due to action of sun. For the thin-walled structures in the change of mechanical behavior crucial aspect for their design, because these changes could arise very quickly. Textile concrete was made by high-strength concrete (100 MPa after 28 days) and styrene-butadiene coated E-glass textile fabric made in Czech Republic. Specimens were preheated to 40, 60 and 80 °C and were subjected to direct tension tests afterwards. It is apparent that with rising temperature, it is mostly the concrete matrix where the biggest decrease of parameters occurs, even its high and commonly presumed good resistance. Results of test showed the slight decrease in glass textile parameters, which is probably caused in a decrease of bond strength between styrene-butadiene coating and textile fabric. However studied topic is highly interesting and should be subjected to following research, because the impact of the environment is the leading factor determining the final service-life of entire structure.

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