STUDY OF PROPERTIES FIBER CONCRETE OF HEAT LOADING

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Abstract:

The aim of the research was to test basic properties of fiber reinforced concrete with PP fibers and cement matrix subjected to heat load of various intensity. Behavior of fiber reinforced concrete was observed in particular from the point of view of change of physico-mechanical properties and microstructure after exposure of test samples to different level of heat load. Volume weight, compressive strength, tensile bending strength, splitting tensile strength and strength in tension of surface layers of concrete were observed.

Keywords: fibre concrete, polypropylene fibres, physico-mechanical properties, heat loading

1 Introduction

The question of resistance of concrete reinforced with polypropylene (PP) fibers is more and more topical. It has been proved that application of PP fibers to concrete is the most effective and the cheapest way of protection of concrete exposed to high temperature and fire, in particular in road tunnels, where PP fiber reinforced concrete is applied in secondary tunnel lining. Road tunnels are places, where occurrence of larger fires as a result of car crashes is quite likely. The volume of fuel of a truck alone can be a source of considerable amount of energy. If a truck transports flammable liquids (fuel, chemicals or even substances for food industry like fats and oils), the situation is even worse. As a result of fire, tunnel lining is subjected to substantial heat loading; temperatures considerably exceed 1000°C. Inner part of a tunnel with fire is exposed to heat loading of different level depending on the distance from the source of fire. Thermal loading causes expansion of water vapor in concrete and consequently cracking of concrete surface and flaking of surface layers, which deteriorates secondary lining.

Application of PP fibers in concrete can limit destructive effects of expanded water vapor. Melting point of polypropylene is between 100-200°C. At these temperatures, PP fibers vaporize from concrete creating small voids in concrete matrix. New porous structure of matrix enables escape of expanded water vapor from the cement matrix without considerable damage of concrete microstructure. This measure limits formation of cracks in concrete structure and flaking of surface layers. It was proved that fibers with higher width to depth ratio are more advantageous. Porous structure of concrete is then

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more interconnected and expanded water vapor can escape more easily without causing any damage to concrete. Use of PP fibers is one of important steps leading to higher resistance of concrete to high temperatures. However, it is also necessary to take into account selection and quality evaluation of aggregate from the point of stability when exposed to high temperatures. Thermal resistance of concrete can be also enhanced by adjustments of concrete matrix composition.

2 Experimental works

2.1 Definition of targets of the research

The aim of the research was to test basic properties of fiber concrete with PP fibers and cement matrix in different level of heat load. Behavior of fiber reinforced concrete was observed in particular from the point of view of change of physico-mechanical properties and microstructure after exposure of test samples to different level of heat load up to 250°C. Volume weight, compressive strength, tensile bending strength, splitting tensile strength and strength in tension of surface layers of concrete were observed.

2.2 Manufacture of test samples

PP fibers by the KrampeHarex Company were used for manufacture of test samples. These fibers are recommended for protection of concrete from the fire effects. Test samples were thermally loaded after 28 days of maturing. After cooling down, the test samples were subjected to different tests. Physico-mechanical properties and changes of concrete microstructure were observed. Mix-design of tested concrete is stated below in Table 1.

Tab. 1 Mix-design of tested concrete

component	kg/m^3
CEM I 42,5 Mokrá	350
Aggregate 8-16 mm Olbramovice	928
Aggregate 0-4 mm Žabčice	892
water	194
Plasticizer Chryso Optima 206	2,3
PP fibers Fibrin 615	2

2.3 Results of experimental work

The main target of experiments was to observe changes of physico-mechanical properties of thermally loaded concrete depending on different level of heat load. Five different levels of heat load were used: 20°C (standardized), 100°C, 150°C, 200°C, 250°C, always with 24 hours dwell time at the set temperature. After cooling down, physico-mechanical properties of samples were tested. Result of the tests are stated below in Table 2.

Tab. 2 Results of tests of physico-mechanical properties

Heat load	Volume weight [kg/m3]	Compressive strength [MPa]	Tensile bending strength [MPa]	Splitting tensile strength [MPa]	Strength in tension of surface layers [MPa]
20°C, standardized placing	2010	21,5	4,2	1,8	2,8
100°C, 24 hours	1940	23,5	4,4	1,85	2,6
150°C, 24 hours	1940	27,5	4,3	1,9	2,2
200°C, 24 hours	1870	23,5	3,3	1,75	1,5
250°C, 24 hours	1930	27	3,2	1,8	1,8

Following diagrams show results of selected physico-mechanical properties of tested concrete.

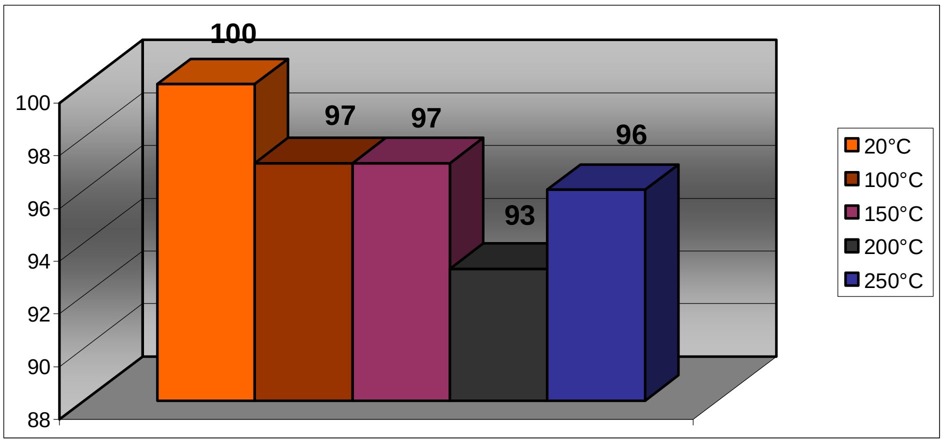

Fig. 1 Comparison of volume weight of tested concrete – percentage

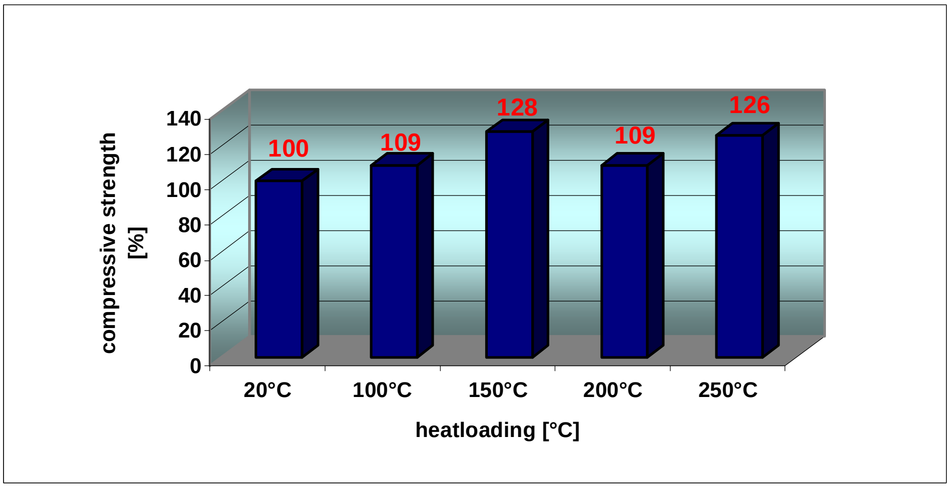

Fig. 2 Comparison of compressive strength of tested concrete - percentage

Microstructure of loaded and reference concrete was studied with optical microscope Nikon, the picture was scanned to computer by TV Sony camera. The picture is projected by software by the LUCIA Company (nowadays LIM Elements); pictures are given below. PP fibers in cement matrix were observed, in particular the shape of PP fibers, extent of vaporisation and formation of fractures and micro-cracks in cement matrix or aggregate of concrete exposed to heat.

Fig. 3 Close up of PP fiber in cement matrix without deterioration – sample not exposed to heat

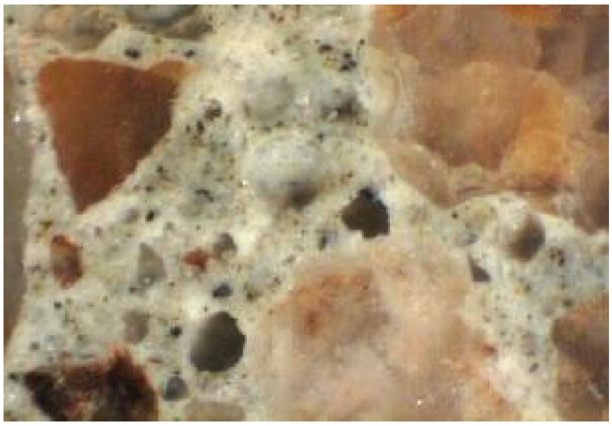

Fig. 4 Close up of undisturbed cement matrix of concrete sample exposed to 250°C

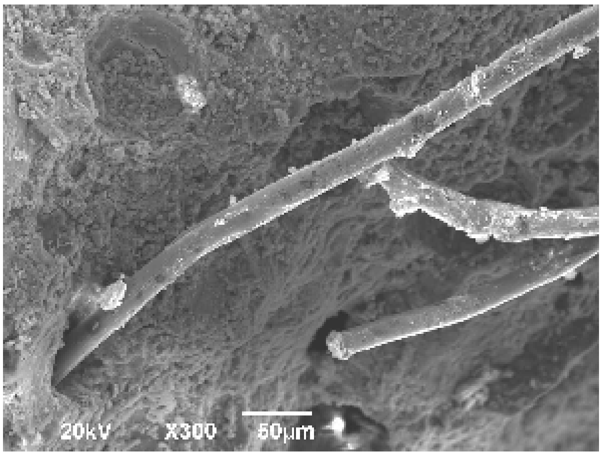

Fig. 5 Close up of PP fiber in cement matrix without deterioration – sample not exposed to heat

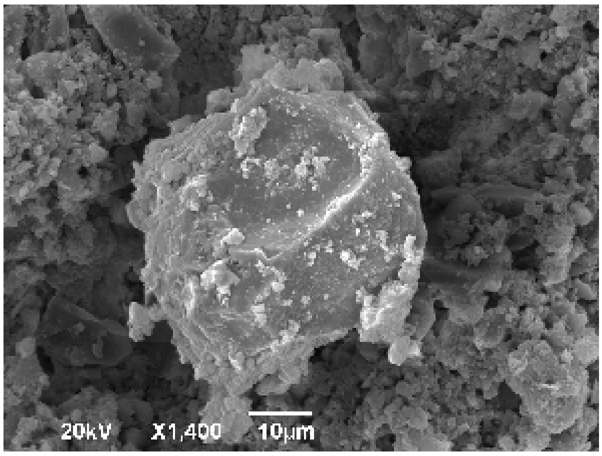

Fig. 6 Close up of partially damaged PP fiber in concrete exposed to 150°C

3 Conclusions

One of the main targets was to verify theoretical knowledge of burning out of PP fibers exposed to thermal loading causing enlargement of porous structure in cement matrix of fiber reinforced concrete. New porous structure of concrete enables escape of expanded water vapor from the cement matrix without considerable damage of concrete microstructure. Visual assessment found that fibers burned out at the surface of samples exposed to 150°C; however, fibers in cement matrix of samples exposed to 100°C remained undisturbed. This was also confirmed by decreasing volume weight depending on growing temperature of heat loading. Difference in volume weight of samples exposed to 20°C and 100°C can be explained by loss of free water in samples of fiber reinforced concrete. Decrease of volume weight of samples exposed to 200°C is probably caused by vaporization of PP fibers, causing higher level of interconnection of porous structure in cement matrix and enabling escape of water vapor enclosed in concrete matrix. However, this will have to be confirmed by more detailed research of micro structure of thermally loaded fiber reinforced concrete and analyses of test samples.

The project also focused on verification of the theory of co-called quasi-reinforcement of concrete, which occurs at heating concrete to 100 - 300°C. As the diagram shows, compressive strength of concrete exposed to high temperature really grew depending on increasing temperature, compared to concrete at normal temperature.

Study of microstructure of thermally loaded samples confirmed visual observation – burning out of PP fibers. PP fibers of test samples not exposed to high temperature and those exposed to 100°C remained in the cement matrix undisturbed. PP fibers of samples exposed to 150°C burned out only at the surface, fibers deep in the sample were only partially deformed by higher temperature. No PP fibers were found nor at the surface, neither inside samples exposed to 200 and 250°C. No micro-cracks or any other damage of cement matrix or aggregate was observed on any of tested samples, i.e. from 20°C to 250°C.

Further research will focus on explanation of non-expected decrease of compressive strength of samples exposed to 200°C and consequent increase of compressive strength of samples exposed to 250°C. This effect was also observed with other physico-mechanical properties except tensile bending strength. Following studies will deal with thermal loading of concrete with cement matrix and PP fibers at higher temperature and more detailed study of microstructure of tested samples.

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