HEAT RESISTANCE OF CONCRETE AND FIBRE CONCRETE

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ABSTRACT

If exposed to high temperatures, concrete and fibre concrete degrade and soon can influence negatively conditions of concrete structure. Changes in a structure of concrete exposed to heat have been monitored in terms of impacts of various temperature on physical and mechanical properties of the concrete. The heat resistance of the fibre concrete is better that that of standard concrete. Surface treatment of concrete and fibre concrete elements increase considerably fire resistance of structures.

Keywords: fibre concrete, resistance of concrete, heat exposure, thermoelectric couples

1 Introduction

If concrete structures are exposed to a fire with temperatures as much as 1 000°C, the statics of the structure is considerably jeopardised. The structure of aggregate and binding materials changes, decreasing in turn strength properties of the concrete. It is well known that in temperatures of about 100°C loose water releases. With higher temperatures, physically bound water releases too. In that stage, quasi-reinforcement takes place in the concrete. This results in a slightly higher compression strength, while the tensile strength and module of elasticity decrease. When the temperature continues increasing, chemical changes in Portland clinker take place. This is the case of both plain concrete and fibre concrete.

The objective of the research was to investigate into behaviour of fibres in the concrete with the temperature being increased gradually up to temperatures exceeding 1,000°C.
For this task, the concrete used for construction of the Klimkovice tunnel has been chosen. The concrete class is C 30/37.

2 Test preparations

Panels with the dimensions 50 x 50 x 20 cm have been produced:

- plain concrete – no fibres
- concrete with Fibrin 615 fibres, weight of fibres: 1 kg
- concrete with Fibrin 660 fibres, weight of fibres: 1 kg
- concrete with Benesteel 50/35 fibres, weight of fibres: 3.0 kg

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Table below shows parameters of the PP fibres.

Fibre type	Length	Equivalent diameter	Quantity/ kg	Specific surface/kg	Tensile strength	E-modulus	Melting point
Fibrin 615	6 mm	17 µm	675 mil.	260 m^2	500 N/mm^2	4200 N/mm^2	160°C
Fibrin 660	6mm	60 µm	20-30 mil.	55 m^2	350 N/mm^2	10 000 N/mm^2	160°C
Benesteel 50/35	35 mm	680 µm	0,085 mil.	-	660 N/mm^2	-	150°C

Table 1 – Used fibres – technical data

After the manufacturing, the panels were maintained in a damp condition for 28-98 days until the testing.
Gas burners supplied with a bottled gas and an auxiliary compressed air were used for heating.
The panels were placed on an insulated concreted structure so that the flame could be in a direct contact with the surface of the concrete.
8 temperature sensors were placed in the concrete panels (5 cm and 16 cm from the heated surface). The temperature was monitored for 120 minutes.

Figure 1 Location of the concrete panel in a heating bench

Figure 2 Temperature sensing in a concrete elements by means of sensors and pickups

Internal sensors (thermoelectric couples) detected heating temperatures. Charts were prepared on the basis of temperatures. Attention was paid to highest temperatures on concrete surfaces and to temperatures inside the concrete.

3 Results

3.1 Changes in the behaviour of test samples in the concrete panels

Maximum temperatures on panel walls ranged between 700° and 1000°C. Temperatures in the concrete panel were distributed along a profile of a concrete element between 420° - 100°C towards the reverse side of the panel.

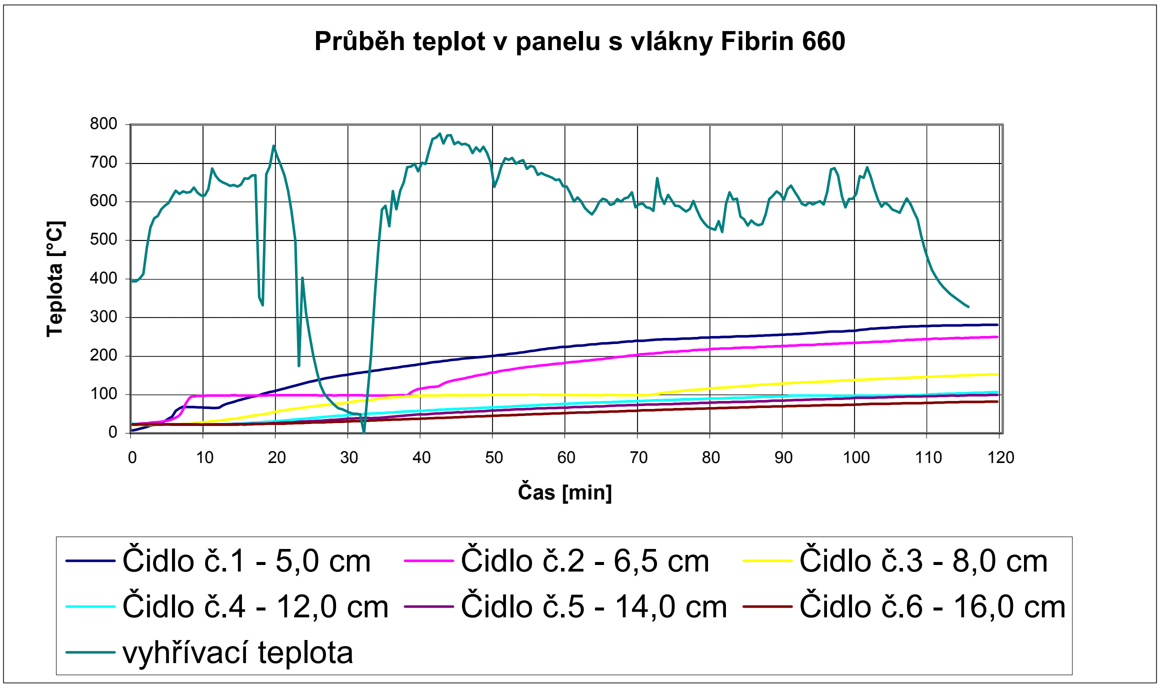

Chart 1. Temperatures in the fibre concrete panel, F 660 fibres

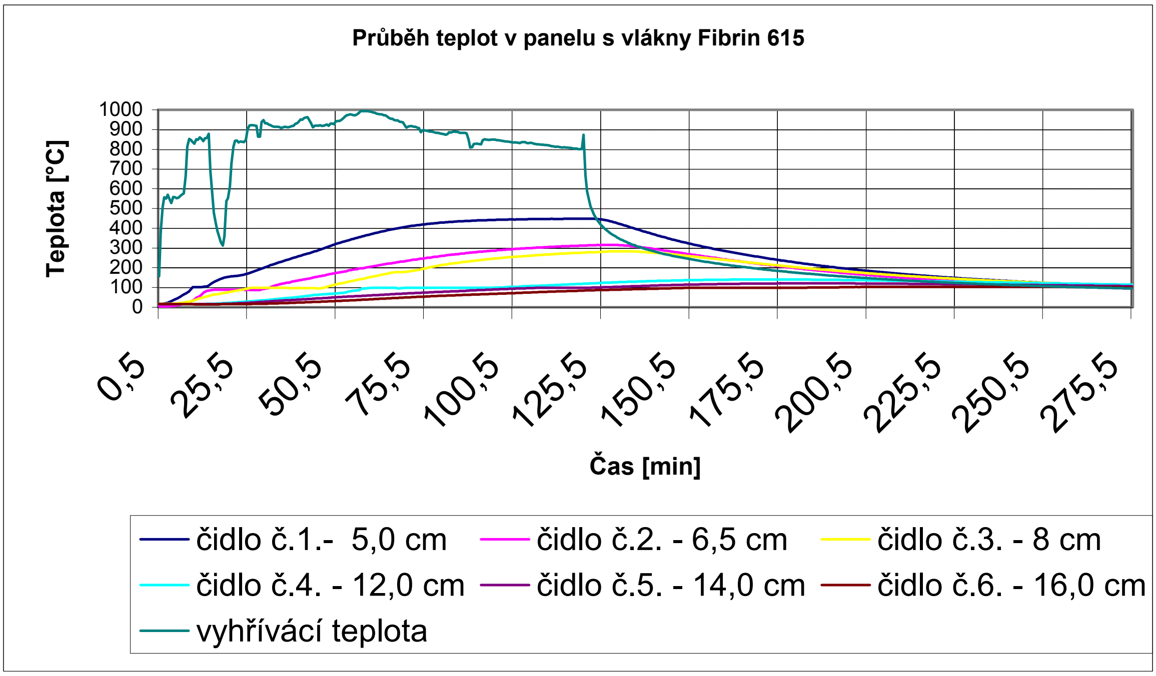

Chart 2. Temperatures in the fibre concrete panel, F 615 fibres

Chart 3.Temperatures in the fibre concrete panel, BS 50/35 fibres

Following conclusions have been drawn on the basis of visual assessment of changes in the concrete panel:

Plain concrete panel: After 10 minutes of heating at 500°C, the surface layer of cca. 15 mm started falling off. See Fig. 3.

Once the temperature reached 772°C, cracks appeared in the block, displacing in turn water and vapours. Finally, the cracks extended to reach **2.5 mm.**

After 30 minutes, the burning of the plain concrete block was stopped.

Fig. 3. Heat-induced damage of the plain concrete panel

F 615 fibre concrete panel: When the temperature reached 994.2°C, micro-cracks started appearing in the block. The crack size reached 1.2 mm. Water and vapours were displaced from the block. The complete block would become damage within less then 120 minutes.

F 660 fibre concrete panel: The maximum temperature was 776.4 °C. External compression defects were same as in F 615.

Benesteel 50/35 fibre concrete panel: Fibres (the size, diameter, and lengths) are more massive than Fibrin fibres. Micro-cracks appeared there as well. The size of the micro-cracks was however 0.2 mm only. Gradually, water and vapours released more and more.

Fig. 4 The panel damaged by cracks and escaping water and vapours

3.2 Changes in physical and mechanical properties

Cubes (with the 150 mm side) were used to validate the temperature distribution in next tests. The cubes were manufactured along with the panels.
The dynamic modulus of elasticity and leakage were evaluated in the samples with the highest surface temperature on the panel.

Before and after the burning, the modulus of elasticity and leakage were monitored too.

Changes in the dynamic modulus of elasticity:

Fibre type	Dynamic modulus of elasticity before burning [GPa] 98 days	Dynamic modulus of elasticity during burning [GPa] at following temperatures					
		230°C	Decrease %	300°C	Decrease %	450°C	Decrease %
No fibres	45,01	37,69	16,26	30,82	31,53	23,63	47,50
Fibrin 615	45,27	34,10	24,67	27,74	38,72	19,21	57,57
Fibrin 660	45,19	39,03	13,63	31,55	30,18	21,67	52,05
Benesteel	46,84	37,29	20,39	32,26	31,13	20,14	57,00

Table 2. Dynamic moduli of elasticity

Leakage depths after heat loading incl. transverse tensile force

Fibre type	Leakage depth at various burning temperatures [cm]			
	230°C	tensile force (MPa)	450°C	tensile force (MPa)
No fibres	8	2,86	9	2,23
Fibrin 615	13	2,52	15	1,55
Fibrin 660	9	3,17	13	1,80
Benesteel	10	2,31	11	1,83

Table 3. Leakages

4 Conclusions

Following conclusions have been drawn on the basis of the visual assessment of defects that appeared in consequent of direct influence of the flame on concrete and fibre concrete panels:

a) - In the plain crack, surface layers exposed to temperatures between 500 and 700°C start falling off.
   - When temperatures increase, cracks appear and extend along the block. Water and vapours escape from the block.
b) - In case of the fibre concrete, the surface of the concrete remained unaffected for 120 minutes, if exposed to a direct flame.
   - - In the fibre concrete block, micro-cracks appeared too. Water and then vapour released gradually.
   - In the fibres with the diameter less than 60 micrometer, the micro-cracks extended to the maximum width of 1.2 mm. When the diameter of the fibres was 600 micrometers, the micro-cracks did not develop.

c) The moduli of elasticity were measured in order to investigate into changes in mechanical properties. In the aforementioned temperature interval, the modulus of elasticity dropped down by 20%-60%.
   - The pressure water leakage does not increase much in the plain concrete. In case of the fibre concrete, micro-pores appear as a result of fibre evaluation, and the whole profile of the heated section starts leaking.

It follows from the results above that heat properties of the fibre concrete are considerably better than those of the plain concrete.

Another group of tests will focus on surface protection of the fibre concrete and on monitoring of changes in the structure of cementing compound.

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