PROPERTIES OF THE FIBRE CONCRETE IN FIRE

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Abstract

In 2011, there were created tests of the composite floor slabs with fibre concrete at ambient and at elevated temperature. At the elevated temperature, slab was only partially protected. By the floor slabs were protected only edge beams. Intermediate beams and fibre-concrete slab were without protection. The concrete slabs were reinforced only by steel fibre without added steel bars. The main aim of the tests was to demonstrate the suitable properties of the fibre concrete in fire. For the fire resistance of the floor slabs it is important that material has a necessary tensile strength and ductility. The material properties of the fibre-concrete allowed to slab created a new load bearing mechanism, which increased fire resistance of the floor slabs. For the experiments were made material properties tests. These tests were created at ambient and at elevated temperature and there were detected ductility and tensile strength of the fibre-concrete.

Keywords: fibre concrete, fire, materials properties, composite slab

1. Introduction

Fire resistance of the composite floor slabs is calculated normally as resistance of the simply construction elements, but fire tests show that floor slabs had a much better fire resistance. This phenomenon is due to a joint acting of simply elements and a membrane acting of the slabs. Due to description of this phenomenon there were tested three slabs with sizes of 4.5 x 3m. The slabs of the thickness 40mm were concrete to trapezoidal sheets TR40/160/0.75. The concrete was reinforced by 70kg per cubic meter. Added steel fibres had the sizes of 0.75 x 50mm and its strength was 1100MPa. Two slabs were tested at the ambient temperature and one at elevated temperature. The tests at ambient temperature were performed in Prague in UTAM and the test at the elevated temperature was performed in Veselí nad Lužnicí in PAVUS (see Fig.1 and 2). For the prediction model, see [1], there were created tests of the materials properties. Concrete mixtures were two. In concreting plants, for each mixture there was made 9 cubes and 9 scantlings.

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Concreting plants were in the towns Jindřichův Hradec and Písnice. Sizes of the cubes were 150x150x150mm and by scantlings these were 150x150x700mm. The cubes were tested in simple compressions and lateral tensile and scantlings in tensile in bend. The scantlings were tested at 20°C, at 500°C and 600°C.

Fig.1: Collapse of the composite slab during the fire test in PAVUS

2. Material properties tests at ambient temperature

The six cubes from concreting plant Písnice reached an average compression strength of 80.9 MPa and three cubes in lateral tension showed by the tests an average tensile strength of 7.4 MPa. This concrete was used on the tests of the slabs at ambient temperature. The six cubes from concreting plant Jindřichův Hradec reached the average compression strength 68.3 MPa and three cubes in lateral tension showed by the tests an average tensile strength 7.1 MPa. This concrete was used on the test of the slab at elevated temperature.

There were tested 2 x 3 scantlings at 21°C. The scantlings were tested by four-point bend, see Fig.3. There is shown a specimen after creation of the macro-crack. The fibre concrete achieved average tensile strength of 6.42 MPa and its average ductility was 1.1 ‰ (concrete plant Jindřichův Hradec). Second concrete mixture achieved average tensile strength of 7.22 MPa and average ductility was 0.92 ‰. This ductility was measured at the initiation macro-cracks. After creating the macro-cracks, stretch was increasing and load bearing capacity was decreasing. The graph of the deflection depending on load is shown on Fig. 4 and 5.

By the tests of the slabs at ambient temperature, the maximum stretching was 1.7%. This volume was calculated from the shape and deflection of the slab. This ductility was measured before the achieving of the global collapse of the slab, but after creating of macro-cracks (yield lines).

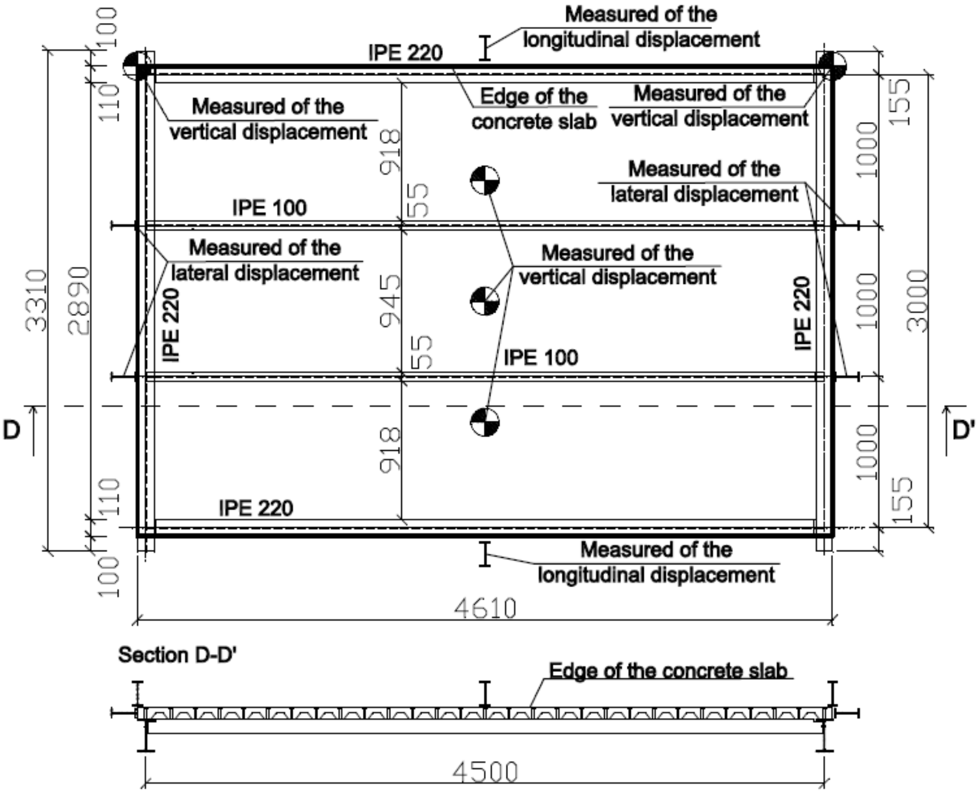

Fig.2. Sizes of the specimen and location of the deflectometers by the test

Fig.3: Scantling after the test (at ambient temperature)

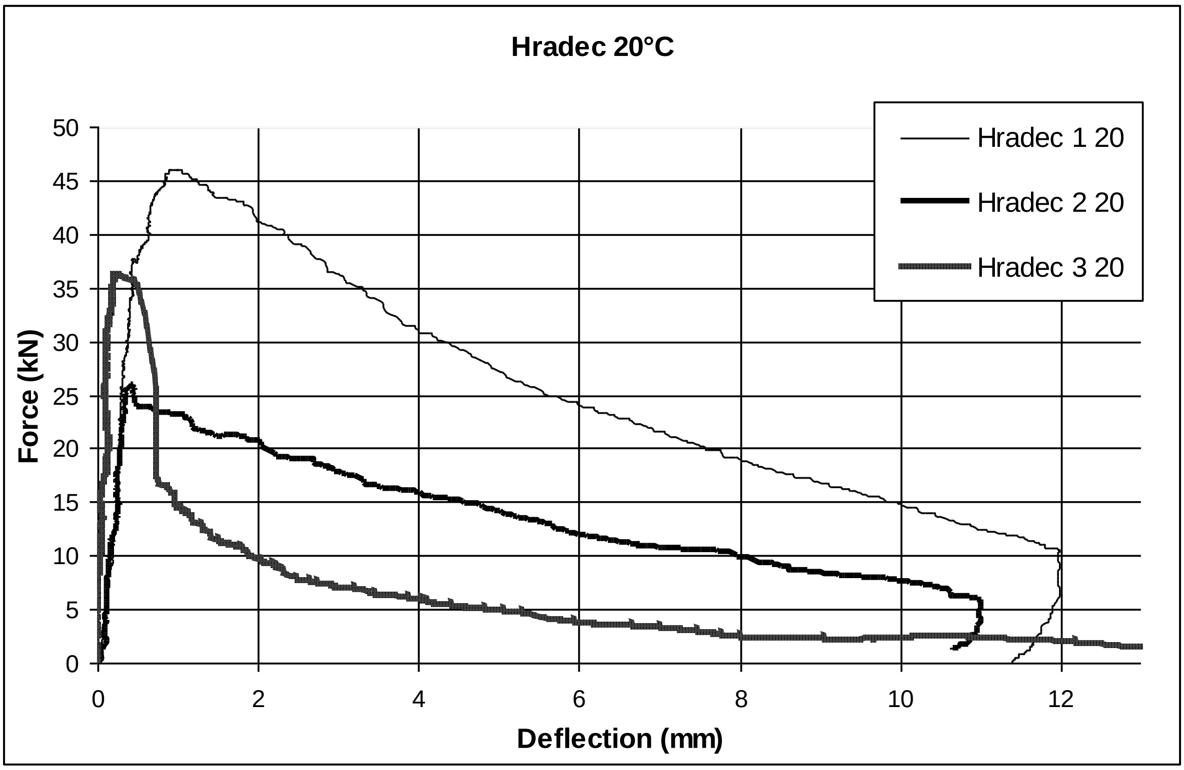

Fig. 4: Diagrams from the test of the concrete specimens at 20°C (Hradec)

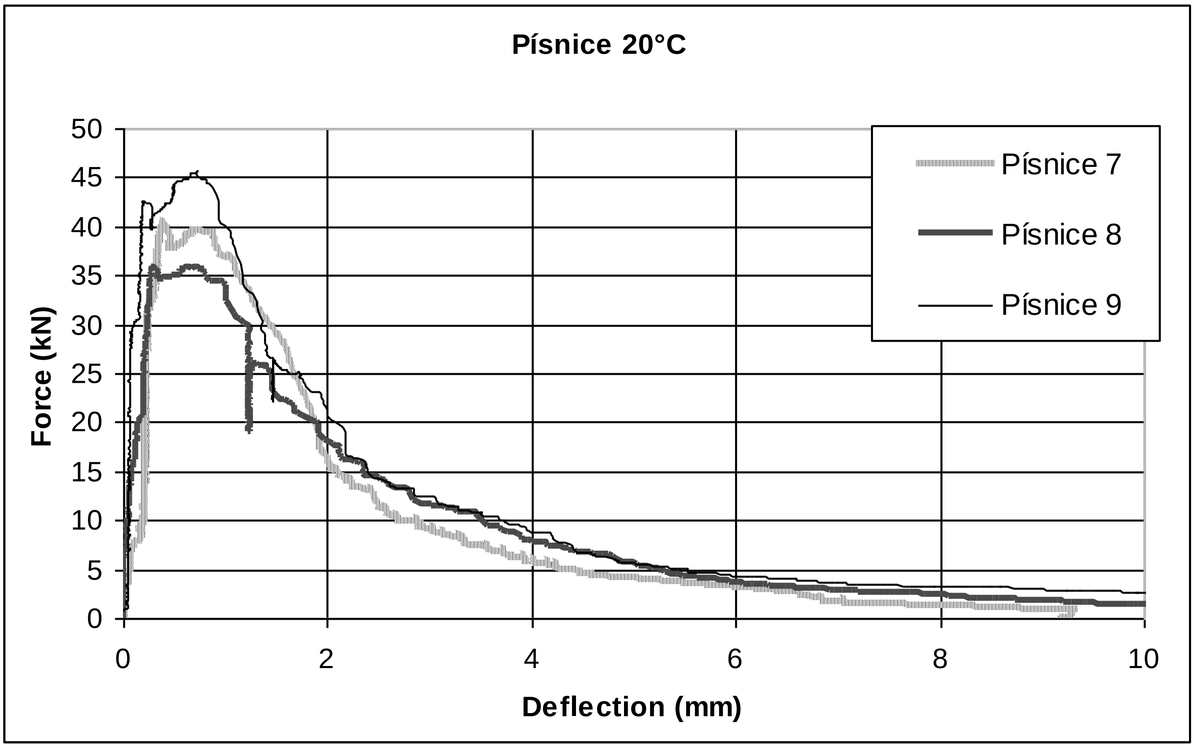

Fig. 5: Diagrams from the test of the concrete specimens at 20°C (Písnice)

3. Material properties tests at elevated temperature

The tested slab at elevated temperature reached the collapse in 195min of the test. Integrity of the slab was maintained during 75 min and criterion of isolation was transgressed after 65min.

Materials property tests were performed on the specimens, which were heated up by five electrical heaters. The specimens were heated to the temperature of 500°C and 600°C. The specimens were thermally protected and were heated up four hours so that the temperature in the scantling is uniformly distributed. The temperature was control by four thermocouples. The deflections were measured by two mechanical deflectometers, which were due to the temperature installed a little while before the loading of a specimen. The loading scheme was the same as by the test at ambient temperature. Fig.7 shows the specimen during the heating. The heating was performed directly in the press. On the Fig. 8 is shown the specimen during the loading.

Fig. 7: The specimen during the heating

Fig. 8: The specimen during loading

3.1 Concrete mixture from concrete plant Jindřichův Hradec

There were tested 2 x 3 scantlings at 500°C and 600°C. The scantlings were tested also by four-point bend. The ductility was calculated at the initiation macro-cracks. The fibre concrete achieved at temperature 500°C average tensile strength of 3.52 MPa and its average ductility was 8.77 ‰. At 600°C it had 1.53MPa and ductility was 6.99‰. On the Fig. 9 and Fig.10 are shown diagrams from the tests. In the Tab. 2 are shown average values of the strength and the ductility a there are calculated values of the coefficient for the given temperature.

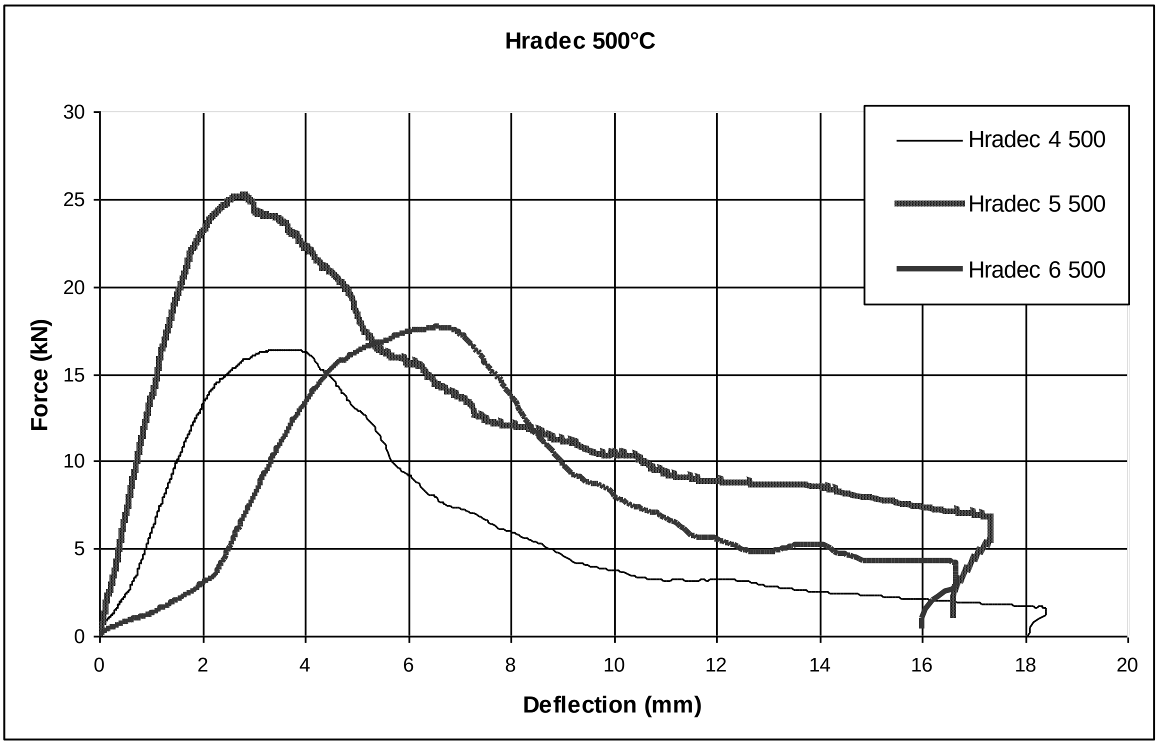

Fig. 9: Diagrams from the test of the concrete specimens at 500°C (Hradec)

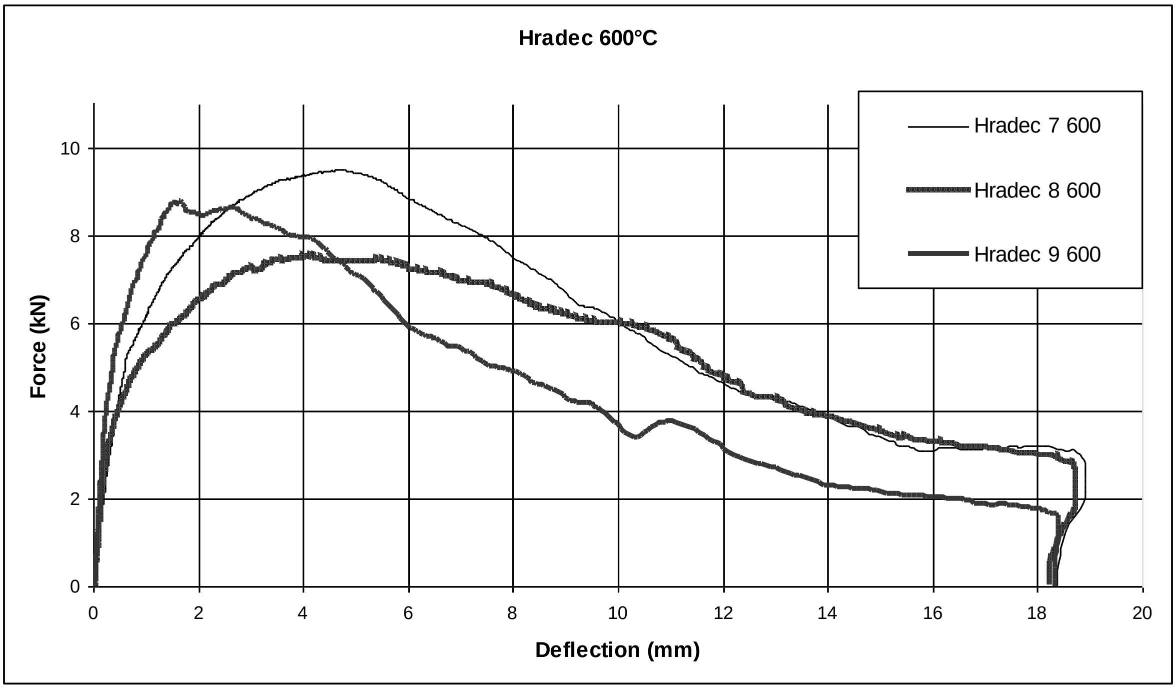

Fig. 10: Diagrams from the test of the concrete specimens at 600°C (Hradec)

3.2 Concrete mixture from concrete plant Písnice

There were tested 2 x 3 scantlings at 500°C and 600°C. The scantlings were tested also by four-point bend. The ductility was calculated at the initiation macro-cracks. The fibre concrete achieved at temperature 500°C average tensile strength of 3.14 MPa and its average ductility was 7.44‰. At 600°C it had 1.37 MPa and ductility was 5.86‰. In the Tab.1 are shown average values of the strength and the ductility a there are calculated values of the coefficient for the given temperature.

Tab. 1: Materials properties in dependency on temperature (Písnice)

specimen	strength [Mpa]	temp. [°C]	average [Mpa]		
Písnice 7	7.17	20			
Písnice 8	6.37	20	7.22		
Písnice 9	8.12	20			
Písnice 1	1.59	500			
Písnice 2	4.25	500	3.14	$k_{\theta,500}$=	0.435
Písnice 3	3.58	500			
Písnice 4	1.86	600			
Písnice 5	1.04	600	1.37	$k_{\theta,600}$=	0.189
Písnice 6	1.21	600			

specimen	ductility ‰	temp. [°C]	average [‰]		
Písnice 7	0.75	20			
Písnice 8	0.55	20	0.92		
Písnice 9	1.44	20			
Písnice 1	3.23	500			
Písnice 2	9.42	500	7.44	$k_{\varepsilon,500}$=	8.124
Písnice 3	9.67	500			
Písnice 4	8.50	600			
Písnice 5	5.82	600	5.86	$k_{\varepsilon,600}$=	6.396
Písnice 6	3.24	600			

Tab. 2: Materials properties in dependency on temperature (Hradec)

specimen	strength [Mpa]	temp. [°C]	average [Mpa]		
Hradec 1	8.20	20			
Hradec 2	4.61	20	6.42		
Hradec 3	6.46	20			
Hradec 4	2.92	500			
Hradec 5	4.49	500	3.52	$k_{\theta,500}$=	0.547
Hradec 6	3.14	500			
Hradec 7	1.69	600			
Hradec 8	1.34	600	1.53	$k_{\theta,600}$=	0.238
Hradec 9	1.56	600			

specimen	ductility ‰	temp. [°C]	average [‰]		
Hradec 1	1.99	20	1.10		
Hradec 2	0.84	20			
Hradec 3	0.48	20			
Hradec 4	7.51	500	8.77		
Hradec 5	5.62	500		$k_{\varepsilon,500}$=	7.940
Hradec 6	13.18	500			
Hradec 7	9.40	600	6.99		
Hradec 8	8.27	600		$k_{\varepsilon,600}$=	6.323
Hradec 9	3.28	600			

4. Conclusions

Fibre concrete demonstrated that its behaviour is similar to behaviour of ductile material. Homogeneity of the fibre concrete was very good, thanks to better mixture of the concrete mix. The rate of average tensile strength at 20°C to 500°C and 20°C to 600°C is similar as coefficient of decrease strength cold-form steel. On the other side ductility of the fibre concrete by 500°C was higher than by 20°C but also by 600°C.

Acknowledgements

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5. References

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