MECHANICAL PROPERITES OF HIGH TEMPERATURE RESISTANCE CONCRETE

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Summary

The paper presents a number of experimental data of high temperature resistant concrete development. Design of special concrete requires an original procedure, because it is not possible to use traditional material sources for concreting. Hydrated Portland cement loses its strength and also chemical changes take place in its mineral composition when it is exposed to high temperature. Resistance to high temperature was observed by mechanical properties changing like compressive strength and three-point bending strength. Presented concrete mixtures were reinforced by various types of fibers to improve fracture properties and aluminous cement was used to provide high temperature resistance. The experimental studies were also conducted to examine the influence of amount of individual components in concrete mixtures to its properties.

Keywords: aluminous cement, basalt fibers, mechanical properties, high temperatures

1 Introduction

In today´s modern civil engineering we put great emphasis on efficient using of non-renewable natural resources. For this reason new buildings design started gradually using high quality entrance raw materials to create super-construction while reducing the overall emission of carbon dioxide. The motivation for this activity is not only the environmental aspect, but also the economic. The increasing price of input materials will significantly reduce the total volume and weight of structures. This leads to cost reduction of other parts of construction.

However, a common problem of new types of structures, made from high performance materials, is their inferior properties in some very specific areas of their proposals. Typical example of these properties is a lack of fire resistance, especially in case of very subtle structures. This deficiency is necessary to be solved by other additional

measures in the form of fire tiling or other kind of measures. Development of fire barriers, which are based on aluminous cement, has become an integral part of building industry, especially with regard to the current global political and security situation. Compared to traditional Portland cement the aluminous has excellent characteristics in relation to the high temperatures and its production is easier and more energy effective. The effectiveness is especially in using redundant energy during night, using electric arc furnace with high efficiency and using chemical clean artificial input materials.

An experimental program, focused on development of new high temperatures resistance composite, is presented here. To ensure sufficient ductility of the resulting composite the matrix on aluminous cement base was supplemented with scattered basalt reinforcement, in this case in the form of fibers.

2 Experimental program

The experimental program was focused on studying mechanical properties like tensile strength in bending and compressive strength of composite made from aluminous cement, various type and amount of basalt fibers, plasticizer and water. The test specimens have dimension 160 x 40 x 40 mm.

Tab. 1 *Composition of the mixtures*

Components [kg·m^{-3}]	CI (1)	CII (2)	CIII (3)	EI (4)	EII (5)	EII (6)
cement	1447.9	1447.9	1447.9	1693.1	1693.1	1693.1
water	506.7	506.7	506.7	423.2	423.2	423.2
fibers	15.3	30.7	46.1	17.9	35.8	53.8
plasticizer	-	-	-	3.3	3.3	3.3
w/c ratio	0.35	0.35	0.35	0.25	0.25	0.25

2.1 Aluminous cement

The original aluminous cement was developed as a mixture of limestone and bauxite. However there is still a place for application of aluminous cement especially in the form of composite materials for high temperature applications.

For the purposes of the experimental program was used aluminous cement manufactured by the French company Lafarge Aluminates SECAR ®71. The main component of the hydraulic binder is aluminium oxide in this case monocalcium – aluminate $CaO \cdot Al_2O_3$. [1]

Tab. 2 *Chemical composition of aluminous cement*

Al_2O_3	CaO	Sio_2	Fe_2O_3	MgO	Na_2O	K_2O
70.8 %	27.5 %	0.58 %	0.42 %	0.21 %	0.27 %	0.06 %

2.2 Basalt fibers

Historical use of the asbestos fibers for high-temperature applications is already overcome due to the health risk, especially laugh cancer. The asbestos is not the only usable material. We can use basalt fibers because they resist with success the temperatures up 1000 °C. In experimental program were used basalt fibers, length 6.35 mm (1/4”) with diameter 13 μm. The density of used fibers is 2900 kg·m^{-3} and tension strength is 2000 MPa. [2]

2.3 Treatment

Due to high hydration heat there were many cracks on the fresh samples which were kept in laboratory condition. This negative phenomenon was eliminate by leaving the fresh cement composite in form in a humid environment with relive humidity over 90 % while avoiding the water evaporation from the surface. [3] The specimen were in steel forms for 72 hours, then removed and till its age 28 days were left in the humidity environment. After 28 days all samples were dried at 105 °C for 24 hours and then the influence of high temperature started being examining.

2.4 Temperature loading

According to paragraph 2.3 all specimens were in age 28 days dried and then divided into three groups each on three specimens. The first group is called reference and the other two were loaded by high temperature 600 °C and 1000 °C.

3 Results

There were designed six mixtures of aluminous composites of aluminous cement, water, basalt fibers and plasticizer. The amount of each components and the water-cement ration is shown in tab. 1. From each mixture were made nine samples, three reference three for temperature load 600 °C and the last three for temperature 1000 °C. The water-cement ration was designed according to suitable workability, therefore it´s lower while using plasticizer. Using the same values of water-cement ratio for mixtures with and without plasticizer leads to segregation of water during compaction because of high efficiency of plasticizer. The fibers were added in 0.5, 1.0 and 1.5 of weight percent.

The results of mechanical properties tests are presented in tab. 3. On all specimens were measured tensile bending strength and compression strength. The mechanical properties are very important parameter for fire resistance materials and for design are important their changes caused by temperature.

Tab. 3 *Mechanical properties*

Mixture	w/c	f_c [MPa]	f_c [MPa] 600 °C	f_c [MPa] 1000 °C	f_t [MPa]	f_t [MPa] 600 °C	f_t [MPa] 1000 °C
CI (1)	0.35	65.9	35.5	23.1	6.8	1.3	0.7
CII (2)	0.35	49.1	26.7	16.3	8.5	2.3	1.0
CIII (3)	0.35	62.8	31.4	19.5	12.0	4.1	1.3
EI (4)	0.25	75.5	61.2	27.3	14.8	8.2	4.5
EII (5)	0.25	101.2	61.8	41.2	14.8	8.2	4.6
EIII (6)	0.25	88.4	52.7	38.8	14.4	8.5	4.5

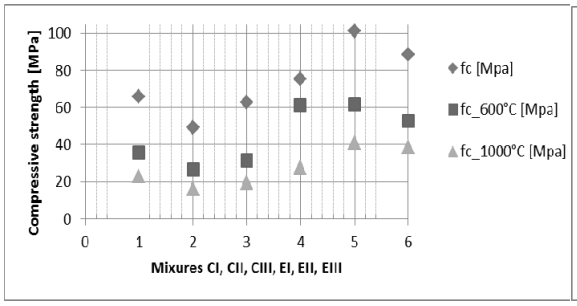

Fig. 1 *Compressive strength*

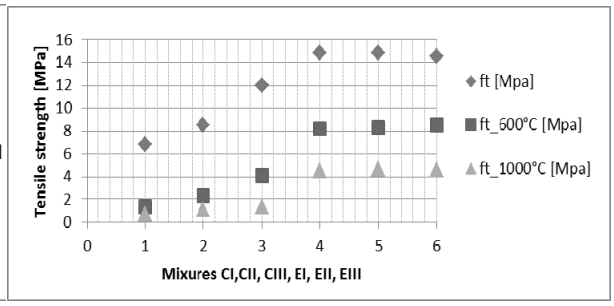

Fig. 2 *Tensile bending strength*

4 Conclusions

The exposure to high temperatures for silicate composites based on Portland cement has completely destructive consequences especially on hydrated cement paste at 500 °C. The complete disintegration of the cement binder takes place at temperatures higher than 800 °C. [4] By the temperature over 600 °C the α-silica is converted to β-silica, which is accompanied by the volume expansion and increasing the tension in inner structure.

Using aluminous cement appropriately supplemented by fibers and plasticizer leads to the creation of composite that resists the effect of high temperatures without volume changes and disintegration of structure. This is very important for design fire resistance facing. The volume stability of presented composite prevents unwanted consequences like explosive spalling. The strength of aluminate cement is also decreased by the influence of high temperature, but the residual strength still ensures cohesiveness and sufficient mechanical properties. The tensile strength was very positively influenced by the value of water-cement ration and the amount of basalt fibers. The strength is shown at fig. 1 and fig. 2. Using of plasticizer while reducing the water-cement ration leads to an increase of compressive and tensile strength of the cement matrix, that results in higher properties.

Acknowledgment

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