THE INFLUENCE OF CEMENT DOSAGE ON THE QUALITY PERFORMANCES OF SPECIAL REFRACTORY CONCRETES

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Abstract. *The objective of this paper is the development of concretes with low dosage of cement and high alumina content (up to 90%). The properties of refractory concretes are related to the dosage of the cement from the concretes. Therefore, a reduction of the dosage cement from concretes from 20% in the case of the common refractory concretes containing normal dosage of cement to the 10-15% for the case of the low cement concretes (LCC) or to the 3-5% for the case of the ultra low cement concretes (ULCC) with the mixtures use are accompanied by the improvement of the mechanical and structural characteristics like strength, porosity, compactness and refractoriness, too.*
Keywords: *Refractory concrete, cement dosage, Low Cement Concrete, Ultra Low Cement Concrete, compressive strength, refractoriness, admixtures.*

1. INTRODUCTION

The creation and use of low cement concretes have certain advantages over concretes with normal cement dosage because the positive effects exercise by the reducing dosage from the concrete.
Thus, the decreasing of proportion of cement [1, 2, 3, 4, 5] in the context of use specific admixtures lead to a low water/cement ratio and to a low apparent porosity which will entail to higher values of mechanical strength and concrete's compactness.
Besides the economic benefits arising from use of less cement content in concrete manufacture, it also presents practical advantages arising from the ease of manipulating materials at achieving concrete structures.

2. CHARACTERIZATION OF THE MATERIALS USED IN EXPERIMENTS

To achieve special refractory concretes were used the following materials: super aluminous cement and aggregates represented by: corundum, bauxite and chamotte and admixtures: reactive alumina, amorphous silica, plastic clay and metal powders and different electrolytes to create coagulation bonds.

2.1. Cement

For achieving the concretes, the super aluminous cement were used, type CA + CA_2.
As it can be seen from Table 1, the proportion of alumina from super aluminous cement used in experimentations exceeded 70% and the presence of free CaO was not found, this shows that this cement is able to create refractory concretes without structural damage caused by subsequent hydration of free CaO (after the normal hardening of the concrete).

Table 1. Chemical analysis of super aluminous cement

Oxide composition, %						
Al_2O_3	CaO	SiO_2	Fe_2O_3	K_2O	Alkalis	Free CaO
72.60	23.89	0.54	0.42	0.07	1.04	-

In Figure 1 is show the particle-size analysis of aluminous cement used as binder in refractory concretes, which shows it advanced grinding fineness (the fraction under 0.06mm was greater than 80%).

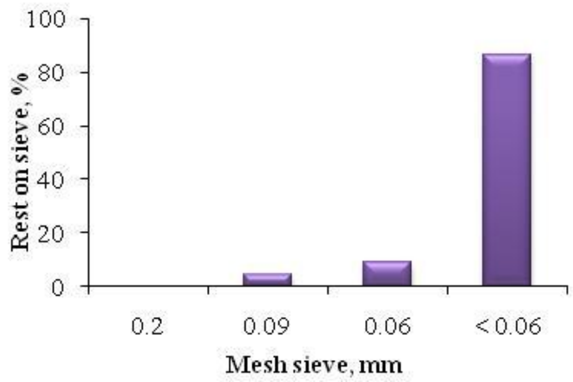

Figure 1. Particle-size analysis of super aluminous cement.

In Table 2 are presented the values of water for standard consistence and the setting time and in Table 3 are shown the values of mechanical strength after 1 day and respectively 3 days. It appears that both in terms of percentage of hardening and of mechanical strength, the properties of use cement fit the product quality standards.

Table 2. The physical characteristics of super aluminous cement

Water for standard consistence, %	Setting time, min.	
	initial	final
31.0	105	255

Table 3. Mechanical characteristics of super aluminous cement

Mechanical strength, MPa			
flexural		compression	
1 day	3 days	1 day	3 days
5.0	5.6	32.5	44.2

2.2. Aggregates

The aggregates perform for making refractory concretes containing between 80-90% Al_2O_3 were bauxite, chamotte D79 and electrocorundum E94.

In Table 4 are presented the physical characteristics and in Table 5 are presented the oxide composition of the aggregates used in carrying out experimental concretes.

Table 4. The physical properties of refractory aggregates

Aggregate	Apparent density, g/cm^3	Absorption, %	Apparent porosity, %
Bauxite	2.98	5.6	17
Chamotte D79	2.07	14.1	29
Electrocorundum E94	3.90	0.7	3

Table 5. Chemical analysis of refractory aggregates

Aggregate	Oxide composition, %					
	Al_2O_3	SiO_2	TiO_2	CaO	Fe_2O_3	Alkalis
Bauxite	85.24	5.42	3.46	0.12	2.0	1.04
Chamotte D79	55.0	36.88	0.38	-	1.79	1.7
Electrocorundum E94	94.0	0.8	2.46	-	0.56	1.46

In figures 2…6 are presented the particle-size distribution of the various aggregates used in experiments and the domain in which the particle-sizes are found.

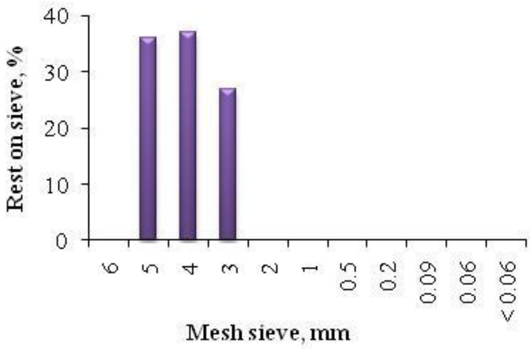

Figure 2. Particle-size analysis of bauxite, 3-6mm.

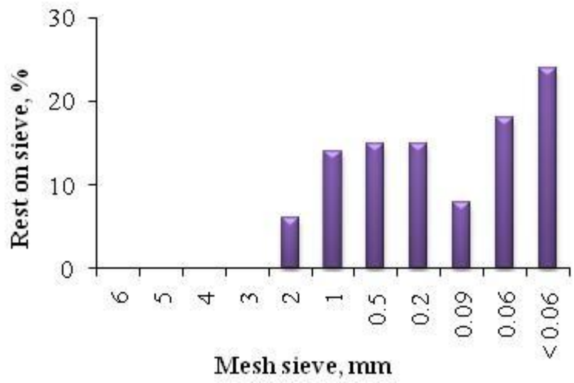

Figure 3. Particle-size analysis of bauxite, 0-3mm.

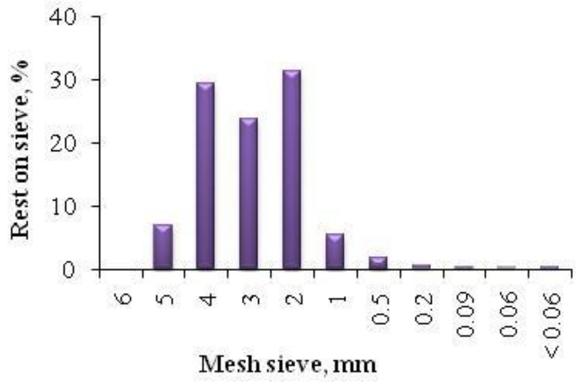

Figure 4. Particle-size analysis of chamotte D79, 0-6mm.

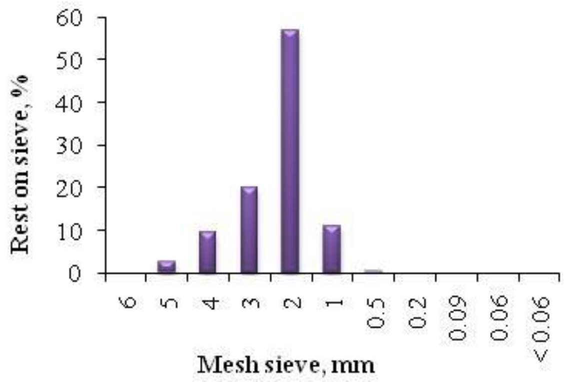

Figure 5. Particle-size analysis of electrocorundum E94, 1-6mm.

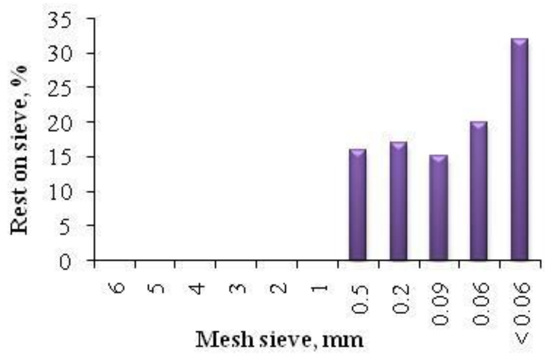

Figure 6. Particle-size analysis of electrocorundum E94, 0-1mm.

Analyzing the data from Figure 4 it shows that chamotte is found in larger particles size (mostly over 1 mm) in the context in which the fine fraction of chamotte is missing. This is of importance because chamotte is the refractory aggregate less noble compared to bauxite and electrocorundum and therefore affects more the refractoriness of the concrete, when is in the fine fraction. Therefore was preferable that the fine fraction of aggregate from concrete to be represented as bauxite (Figure 3) and electrocorundum (Figure 6).

2.3. Additives, admixtures, electrolytes

To realize the concretes in which the cement content can be reduced from 20%, the normal proportion of cement which is found in a normal refractory concrete to low values of cement, characteristic to the low cement concretes, it must be used in addition to cement, other admixtures (see Table 6) in order to develop other types of bond in addition to the hydraulic one.
These types of bonds that occur and contribute to the structural integrity of these special types of concretes are: condensation-coagulation bond, which occurs at normal temperature, chemical and ceramic bonds that show their presence at high temperatures [2, 4, 6, 7].

Table 6. Raw materials use as admixtures, additives and electrolytes

Raw material	Oxide composition,%				
	Al_2O_3	SiO_2	CaO	Fe_2O_3	Alkali s
Refractory alumina	22.76	56.92	-	4.23	3.57
Amorphous silica	0.47	87.4	1.2	1.74	1.19
Reactive alumina	99.8	-	-	0.02	0.11
Silicon	min. 93% Si				
Sodium Tripolyphosphate	min. 55% P_2O_5				

3.RESULTS AND DISCUTIONS

The concrete masses, and the proportions used of cement, aggregates, additives, admixtures and electrolyte for carry out this concrete masses are presented in Table 7.

Table 7. Composition of refractory concretes

Component	Concrete composition, %		
	I	II	III *
Bauxite, 3-6mm	32.13	-	35
Bauxite, 0-3mm	52.93	-	45
Chamotte D79, 0-6mm	-	23.63	-
Electrocorundum E94,1-6mm	-	23.63	-
Electrocorundum E94, 0-1mm	-	37.80	-
Aluminous cement	9.45	9.45	20
Reactive alumina (p. 100%)	1.9	1.9	-
Amorphous silica (p. 100%)	0.47	0.47	-
Silicon (p. 100%)	0.95	0.95	-
Refractory clay (p. 100%)	1.9	1.9	-
TPP (p. 100%)	0.27	0.27	-
Water requirement	15.5	15.5	17.5
pH	10.5	10.5	10.0

* The reference concrete

In Figure 7 are given the particle-size composition of the dry mixtures of concretes investigated.

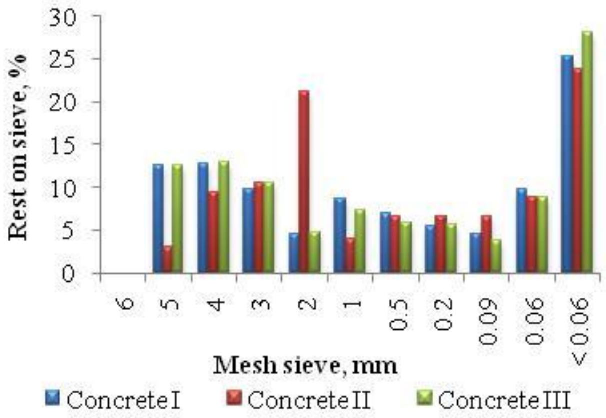

Figure 7. Particle-size analysis of refractory concretes.

Analyzing the data presented in Figure 7 it can be seen a difference between the coarse grains of experimental masses of Concrete I and II, this is due to the different types of aggregates used for Concrete I bauxite, and a mixture of chamotte and electrocorindon for Concrete II. Regarding the Concrete III, which is made with the same type of aggregate as the Concrete I, the coarse component distribution is somewhat similar.
To achieve compact structures was used a high proportion of ultra fine fraction, under 0.06 mm, important as a share, this having a major role in achieving the adequate structural compaction.
In Table 8 is presented the oxide analysis of the low cement concretes (Concrete I and II) and of the Concrete III with normal cement dosage, which has represented the reference concrete.

Table 8. Chemical analysis of concretes

Concrete	Oxide composition, %					
	Al_2O_3	SiO_2	CaO	TiO_2	Fe_2O_3	Alkalis
I	82.23	8.65	2.71	2.95	1.98	1.04
II	82.31	10.80	2.78	1.72	0.80	1.56
III	82.88	5.32	5.58	2.80	1.86	1.12

As it can been seen from the data presented in Table 8, the content of alumina from the concretes studied is between 82.23 and 82.88%, which confirms that studied concrete has a high content in Al_2O_3.
In Figure 8 is shown the compressive strength of concretes dependent on the heat treatment temperature determinate on samples with sizes 40×40×160 mm, made by casting-vibration, hardened for three days and dried at 110^0C.

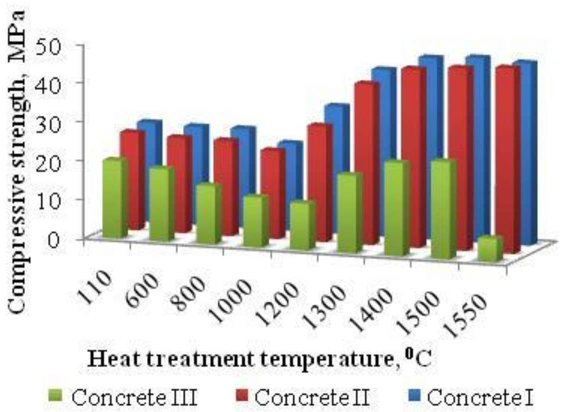

Figure 8. Compressive strength dependent on the heat treatment temperature.

As you can see the compressive strength of the Concrete I and II (with low content of cement - 10% and additives) are higher than those corresponding to the concretes with normal cement content and additives, both at normal hardening and dry at 110^0C, and under conditions of heat treatment at higher temperatures.
It can be seen by analyzing the data presented in Figure 9, that in the temperature interval 800-1200^0C is registered in the case of reference concrete an important loss of compressive strength comparative with Concrete I and II where the phenomenon is much reduced.
This behaviour is typical for refractory concretes and occurs in so-called "critical temperature range" (600-1200^0C) is due to textural - structural changes which the new formation of hydration undergo (resulted from cement hydration in normal condition) at heating, process which is accompanied by the transition from hydraulic bond to ceramic bond.
Obviously, the process of decreasing the compressive strength is even lower as the proportion of hydraulic new formations (resulting from cement hydration) is higher, implicitly as the proportion of cement in concrete is higher.

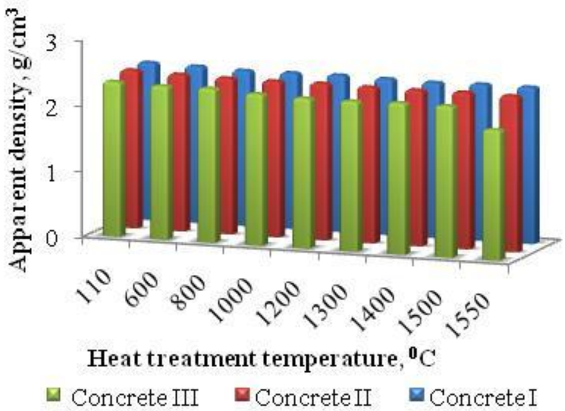

Figure 9. Apparent density of concretes dependent on heat treatment temperature.

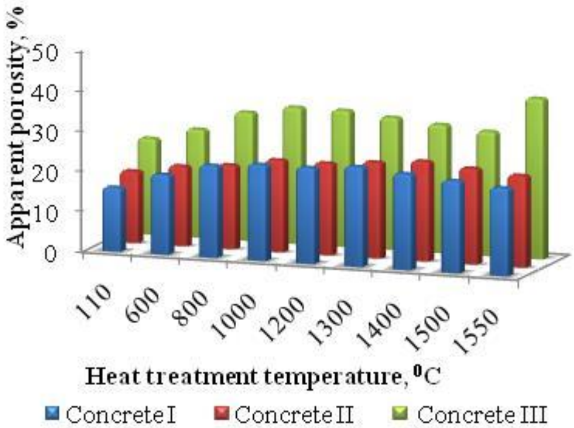

Figure 10. Apparent porosity of concretes dependent on heat treatment temperature.

The refractory aluminous concretes with low dosage of cement and additives are characterized by a low porosity compared with Concrete III, both at free hardening and in heat treatment conditions. This is due to the binder matrix because is in a lower proportion, its influence is lower in concrete.
Likewise acts the admixtures which have the property to influence the pores size, as also influence the pore size distribution to a maximum pore size.
A higher apparent porosity leads to lower compactness and of course lower results on the behaviour of hard concrete, which can be observe when compared to Concrete III.

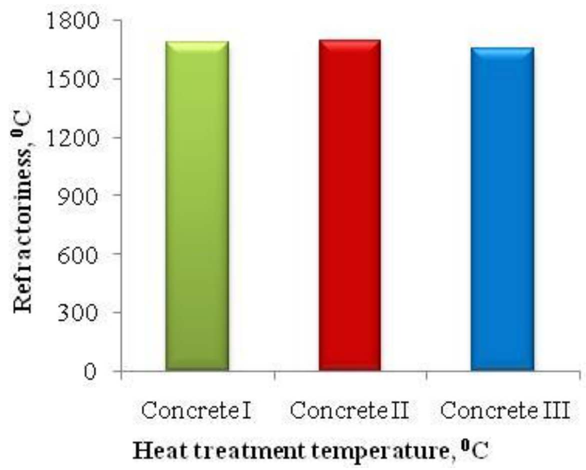

Figure 11. Refractoriness of concretes.

As can be seen from Figure 11, the refractoriness of concretes with lower cement dosage is higher, this is in accordance with the lower value of cement dosage, is known the fact that the cement represent the flux component of refractory concrete.

Superior results obtained for concrete with low cement dosage are confirmed by investigations carried out by X-ray diffraction which brought at high temperature correspond to ceramic bound the formation of mineralogical compounds: monocalcium aluminates - CA (lines 2.97 Å, 2.60 Å, 2.51 Å), dicalcium aluminates - CA_2 (lines 3.52 Å, 4.44 Å, 2.76 Å) which contribute to the high mechanical strength of refractory concretes with low cement dosage. In addition to these compounds the anorthit - CAS_2 (lines 4.02 Å, 3.23 Å) and mullite - A_3S_2 (lines 3.39 Å, 3.43 Å) are also met. These constituents formed at high temperature enhance the mechanical strength of concrete by forming strong bridges matrix-aggregate.

4. CONCLUSIONS

The low cement concretes present mechanical strength at free hardening and at heat treatment, superior to concretes with normal cement content (20%), due to additives used that make to appear beside hydraulic bond, the coagulation-condensation bond, too.

The low cement concretes exposed in the critical temperature range depreciation of mechanical strengths, lower compared to conventional refractory concretes.

Refractory concretes I and II presents an apparent porosity lower than reference concrete III because the matrix is more compact than that of the reference one.

Structural change of the matrix porosity is one the reasons of which the concretes with additives shows more compact matrix, which are characterized by higher values of density, compared with reference concrete.

Refractoriness of the concretes with additives (1680-1690^{0}C) is proven to be superior to the reference concrete (1650^{0}C) due to reduced proportion of binder phase of which this concrete contains.

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