POSSIBILITY OF PRODUCTION OF METALLURGICAL CEMENT TYPE CEM III/A 42.5N IN CEMENT PLANT KAKANJ

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ABSTRACT
This paper examines the possibility of producing metallurgical cement type CEM III/A 42.5N at the Kakanj Cement Factory. The tested samples contain respectively 46%, 41%, and 38% of granulated blast furnace slag and the rest is clinker. According to the test results, all cement samples meet the EN 197-1 standard in terms of physical-mechanical properties both after the initial period (2 days) and after the final period (28 days). As a result of the conducted tests, it can be concluded that the production of metallurgical cement type CEM III/A 42.5N at the Kakanj cement factory is possible and that its production would provide a number of ecological and economic benefits.

1. INTRODUCTION

By reducing the clinker content and using granulated blast furnace slag in the production of cement, it is possible to reduce CO_2 emissions during production. If the content of clinker in cement is reduced, the number of natural resources needed for the production of clinker will also be reduced, thus having a positive effect on the preservation of ecology. Also, using a larger amount of granulated blast furnace slag for cement production opens up the possibility of producing cheaper cement because granulated blast furnace slag is a much cheaper material than clinker itself.

Metallurgical cement is obtained by grinding Portland cement clinker, gypsum, and granulated blast furnace slag, the content of which ranges from 36 to 95%. According to EN 197-1, metallurgical cement belong to the third group of cement (CEM III) and there are three classes of metallurgical cement, namely [1]:

- CEM III/A with granulated blast furnace slag content of 36 – 65 %,
- CEM III/B with granulated blast furnace slag content of 66 – 80 %.
- CEM III/C with granulated blast furnace slag content of 81 – 95 %.

The constituents discussed in this paper are:

- clinker produced in the Kakanj cement plant,
- granulated blast furnace slag of the company ArcelorMittal Zenica

2. EXPERIMENTAL

2.1 Materials and method

If one part of clinker, as the main ingredient of cement, is replaced with a certain amount of granulated blast furnace slag, the already existing depositing of granulated blast furnace slag is reduced, natural raw materials are saved, environmental pollution is reduced, and in

the end, cheaper cement can be produced. Also, using a larger amount of granulated blast furnace slag would reduce CO_2 emissions into the atmosphere. Of course, in order to produce this kind of metallurgical cement, the requirements of the EN 197-1 standard must be met.
Clinker is produced by a sintering process from a precisely specified mixture of raw meals. Clinker is a hydraulic material that mostly consists of four main minerals that give it a certain reactivity, namely alite (C_3S), belite (C_2S), tricalcium aluminate (C_3A), and tetracalcium ferrite (C_4AF). Granulated blast furnace slag (GBFS) is a byproduct of the iron production process in blast furnaces. It is a latent hydraulic material, because during the hydration of cement after the release of $Ca(OH)_2$, the hydration of the blast furnace slag continues unhindered. This means that for practical use an activator is needed to react with water and form hydrated phases similar to clinker hydration products. It is obtained when coke ash and limestone are added to iron ore to remove impurities. In the process of extracting iron from iron ore, a liquid slag is formed, consisting primarily of calcium silicates and aluminosilicates, and other phases, and it floats on top of the liquid iron. The liquid slag is separated from the liquid metal and cooled. If the liquid slag is rapidly cooled with water, granulated blast furnace slag is obtained. By grinding granulated blast furnace slag improves its reactivity during cement hydration [2,3].
The chemical analysis of clinker and granulated slag from blast furnaces is determined by XRF spectrometry and mineralogical composition was determined by diffractometer. The aim of this work is to examine the possibility of producing metallurgical cement type CEM III/A 42.5N in the Kakanj cement factory with the composition U1 (50% clinker, 46% granulated blast furnace slag, and 4% gypsum), U2 (55% clinker, 41% granulated slag blast furnace, and 4% gypsum) and U3 (58% clinker, 38% granulated blast furnace slag, and 4% gypsum). For the preparation of each sample, about 2 kg of the mixture (clinker, granulated blast furnace slag, and gypsum) was weighed. After grinding, the sample was shaken out of the ball mill, then sieved on a 1 mm sieve, and taken to the laboratory for further testing. The samples were kept in a room with a temperature of 20 ± 2 °C and relative humidity > 50 %.In this work, it will be investigated whether the new class of cement U1, U2, and U3 retains the properties of cement given by the already existing CEM II/B – W 42.5N composition of 68% clinker, 28% fly ash, and 4% gypsum.
Standard consistency, setting time, and volume constancy are determined according to EN 196 – 3 [4].

2.2 Test results

Table 1 shows the chemical analyses of clinker and GBFS. Table 2 shows the mineralogical composition of clinker and GBFS. In order for clinker and GBFS to be used for cement production, certain requirements must be met according to the European standard EN 197 – 1 (Table 3) [1].

Table 1. Chemical composition of clinker and GBFS

Component (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Chloride
Clinker	20,84	5,64	3,02	66,62	1,10	0,57	0,14	0,52	0,009
GBFS	41,44	7,60	0,88	38,88	4,89	0,09	0,24	1,28	0,008

Table 2. Mineralogical composition of clinker and GBFS

Minerals	Clinker (%)	GBFS (%)
Alit (C_3S)	59,93	
C_2S	16,38	
C_3A	10,36	
C_4AF	8,39	
Free CaO	1,11	
Periclase (MgO)	0,19	
Quartz (SiO_2)	0,08	
Arcanite (K_2SO_4)	1,22	
Portlandite ($Ca(OH)_2$)	0,01	
Amorphous phase		99,70
Calcit		0,20
Mervinit		0,01
Quartz		0,04

Table 3. Requirements of EN 197-1 for clinker and GBFS [1]

	Requirements EN 197-1	Clinker	GBFS
$C_3S + C_2S$	≥66,6 %	76,31 %	
CaO/SiO_2	>2,0	3,20	
MgO	<5,0 %	1,10 %	
$CaO+MgO+SiO_2$	≥66,6 %		85,21 %
$(CaO+MgO)/SiO_2$	>1,0		1,057

Table 4. Chemical composition of metallurgical cement

Sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O
U1	28,98	6,43	2,28	51,53	3,84	2,75	0,18	0,84
U2	28,03	6,33	2,35	53,03	3,55	2,33	0,17	0,81
U3	27,46	6,27	2,39	53,92	3,37	2,32	0,16	0,79

Table 5 shows the physical and mechanical properties of the metallurgical cement examined in this paper, while Table 6 shows the requirements of the EN 197-1 standard for the physical-mechanical properties of cement.

Table 5. Physical and mechanical properties of cement

	R 009 (%)	Specific surface (cm^2/g)	Stand. conc. (%)	Setting time		Compressive strength (MPa, days)			
				Initial (min.)	Final (min.)	Flexural		Compressive	
						2	28	2	28
U1	0,1	4340	25,2	125	145	2,7	7,2	12,8	45,8
U2	0,1	4260	25,6	120	150	2,7	7,5	13,0	47,6
U3	0,1	4300	25,6	110	145	2,8	7,3	14,0	47,9
CEM II/B-W 42,5N	0,5	3450	27,0	185	245	2,9	7,9	15,0	50,4

Table 6. Requirements of EN 197-1 for physical-mechanical properties of cement [1]

Strength class	Compressive strength (MPa, days)				Initial setting time (min)	Soundness (mm)
	Early strength		Standard strength			
	2 days	7 days	28 days			
32,5 N	-	≥ 16,0	≥ 32,5	≤ 52,5	≥ 75	≤ 10
32,5 R	≥ 10,0	-				
42,5 N	≥ 10,0	-	≥ 42,5	≤ 62,5	≥ 60	
42,5 R	≥ 20,0	-				
52,5 N	≥ 20,0	-	≥ 52,5	-	≥ 45	
52,5 R	≥ 30,0	-				

3. DISCUSSION

The clinker also meets all the requirements of the European standard EN 197-1. The total content of CaO, SiO_2, and MgO in granulated blast furnace slag according to the EN 197-1 standard must be greater than 66.6%, and the granulated blast furnace slag used for these tests has a content of these components of 85.21 %. The standard consistency of all cement samples is very similar and ranges from 25.20 to 25.60 %. The difference at the beginning of the setting time between the samples is insignificant and the shortest setting time at sample U3 (110 minutes), which can be attributed to the highest content of clinker compared to the other samples, while the difference at the end of setting between the cement samples is about 5 minutes.

Regarding the compressive strength results, all three samples (U1, U2, and U3) have compressive strength values after 2 days greater than 10 MPa (12.8 MPa, 13.0 MPa, and 14.0 MPa) and they meet the requirements of the EN standard 197-1. After 28 days, all samples meet the requirements of the EN 197-1 standard in terms of compressive strength and have values greater than 42.5 MPa.

4. CONCLUSIONS

According to the test results, all cement samples meet the EN 197-1 standard in terms of physical-mechanical properties both after the initial period (2 days) and after the final period (28 days). In general, increasing the content of mineral additives (granulated blast furnace slag) and decreasing the clinker content opens up the possibility of many benefits. The production of the new class of cement U1, U2, and U3 would reduce the production of clinker by the corresponding percentage of clinker while maintaining the properties of the cement provided by the existing CEM II/B – W 42.5N. The Kakanj cement factory currently produces CEM II/B – W 42.5N with a clinker content of about 68 %, and if U1, U2, and U3 cement containing 50 %, 55 %, and 58 % of clinker were produced, the utilization of natural resources, i.e. raw materials for the production of clinker, and as a consequence CO_2 emissions into the atmosphere would also decrease. As a final goal, financial benefits would be achieved because clinker is the most expensive component in the production of cement. On the other hand, the consumption of granulated blast furnace slag would increase, which would mean less accumulation of this material in existing landfills. All three types of cement (U1, U2, and U3) would have the mark CEM III/A 42.5N.

5. REFERENCE

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