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Solid waste management

INVESTIGATION OF USAGE OF THE FLY ASHES FROM POWER PLANTS KAKANJ AND TUZLA IN PORTLAND CEMENT PRODUCTION

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Abstract. The fly ash, a massive solid waste from coal fired power plants is produced with a crude estimation of 700 billion t per year in the world, and only 6% of this quantity are utilised in cement production. The aim of the present work is to investigate the possibility of using the fly ashes from power plants Kakanj and Tuzla for cement production. The fly ash utilisation has economical as well as ecological benefits. According to national standard BAS EN 197-1, the fly ash is used as a supplement in cement production. On the basis of chemical composition fly ash can be classified in two main categories: alumino silicate and calcium silicate fly ashes. Both investigated ashes belong to the group of calcium silicate ashes with high CaO content. However, fly ash from power plant Tuzla has higher content of CaO and lower content of SiO_2 comparing to fly ash from power plant Kakanj. Regardless on fly ash content in the cement, the initial setting time is longer than 60 min, and this condition is defined by standard. The initial setting time increases with increasing the fly ash content in the cement. The soundness was investigated on samples with different fly ash content. It was observed that all the samples tested shown expansion much smaller than standard limited expansion. This is consequence of very low free CaO content and it is very important characteristic concerning the durability of cement-based products. Generally, cements with fly ash content gain strength more slowly at early ages (28 days). It was determined that samples manufactured of cement with fly ash from power plant Kakanj have greater strength than samples with flay ash from powerplant Tuzla. The results obtained show that the fly ash from power plant Kakanj is more favourable supplement for cement production. Apart from chemical composition, this fly ash has other advantages over the fly ash from power plant Tuzla such as high content of glassy phase (>50%), low content of unburned coal and free CaO and very high content of fine particles (<20 μm).

Keywords: fly ash, power plants, portland cement production.

AIMS AND BACKGROUND

World-wide we are facing the issue of dealing with solid waste material, as well as solid waste dumps due to which we have the need for its utilisation. One of those issues is electric filter ash from thermal power plants. During the combustion of grounded coal in boilers of thermal power plants ash particles, which are released together with flue gases, accumulate on electric filters. This ash is being called

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fly ash and represents approximately 85% of the total amount of ash in thermal power plants[1].

The global production of fly ash is about 700 million t annually, while only 6% of this waste material are being exploited in the production of cement[2,3].

According to the Bosnian and Herzegovian BAS standard EN 197-1, one of the additives used in cement production is fly ash, which by nature can be mixture of aluminium and calcium silicates. The first has pucolanic features, while the second one can have hydraulic characteristics as well. Both types of ashes must not have lost during annealing greater than 5% of weight.

Silicate types of fly ashes are fine powders of mainly spherical particles, which has pucolanic features and basically needs to contain reactive SiO_2 and Al_2O_3, while the rest is Fe_2O_3 and other oxides. Content on reactive SiO_2 must not be less than 25% while the content of reactive CaO must be below 5%.

Calcium types of fly ashes are fine powders which possesses both hydraulic and pucolanic characteristics, essentially consisting of reactive CaO, SiO_2 and Al_2O_3, while the rest with this form of ash as well is Fe_2O_3 and other oxides. The amount of reactive CaO must not be less than 5%.

EXPERIMENTAL

In the experimental part of this work, for the preparation of cement samples the following materials were used: cement clinker from the cement factory Kakanj, fly ashes from TEPS Kakanj and TEPS Tuzla and gypsum.

Preparation of cement samples. The 6 cement samples for investigation were prepared on laboratory level by mixing of grinding cement clinker from cement factory Kakanj with the both fly ashes. To each samples 4% of gypsum were added as well. The composition of the cement samples are shown in Table 1.

Table 1. Composition of cement with various share of fly ashes

Cement index	Mass share od certain components (%)		
	clinker	gypsum	fly ash
PC0	96	4	0
PC10	86	4	10
PC20	76	4	20
PC30	66	4	30
PC40	56	4	40
PC50	46	4	50

From Table 1 one can notice that the cements are marked with index PC (Portland cement) and with number that represents the weight percentage of ash in cement. All cements were milled to specific surface area of approximately 3000 cm^2/g. As it can be seen from Table 1, all cements have the same content of gypsum which acts as regulator of binding.

The raw materials and prepared cement samples were examined for their physicochemical characteristics.

Physicochemical characteristics of fly ashes. For chemical analysis of initial raw materials and prepared cement samples we used the method of fluorescent spectrophotometry (XRF). Chemical analysis of both the electric filter ashes is presented in Table 2.

Table 2. Chemical composition of ashes

Component	TEPS Kakanj	TEPS Tuzla
	(mass. %)	
G.Z.	0.95	1.34
SiO_2	39.8	51.78
Fe_2O_3	7.15	8.38
Al_2O_3	20.48	20.27
CaO	25.6	9.11
CaO (free)	0.96	0.46
MgO	1.64	3.02
SO_3	1.57	1.56

A MICROSIZER particle analyser model 201C was used for measuring the particle size distribution of fly ashes. This analyser is designed for rapid measurement of the distribution of weight shares of particles by sizes in suspensions. The results of granulometric analysis of ashes, as well as their particle size distribution are presented in Tables 3 and 4.

Table 3. Granulometric composition of fly ash from TEPS Kakanj

d*S** 50%	< 1 μm (%)	< 3 μm (%)	< 4 μm (%)	< 5 μm (%)	>10 μm (%)	>15 μm (%)	>20 μm (%)	>30 μm (%)
7.86 μm	8.0	26.6	33.3	38.7	42.8	27.9	15.3	2.4

*mean particle size.

Table 4. Granulometric composition of fly ashes from TEPS Tuzla

d*S** 50%	< 2 μm (%)	< 5 μm (%)	<20 μm (%)	<30 μm (%)	<45 μm (%)	<80 μm (%)	<100 μm (%)	>150 μm (%)	>300 μm (%)
106 μm	1.0	2.4	7.6	10.5	13.4	16.4	45.6	26.5	3.5

*mean particle size.

As a regulator of binding a raw gypsum was used from the deposit Bistrica near Gornji Vakuf and its chemical analysis is shown in Table 5.

Table 5. Chemical composition of gypsum

Component	GZ	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3
Mass. %	17.17	4.52	0.81	1.62	30.31	3.59	38.15

Features of the prepared cements. Tables 6 and 7 show the results from the examination of the main characteristics of the cements with the addition of ashes from the both thermal power plants.

Table 6. Characteristics of cement with addition of ashes from TE Kakanj

Clinker (%)	Ashes (%)	Plaster (%)	R009 (%)	Specific weight (g/cm³)	Specific surface (cm²/g)	Standard consistency (%)	Binding (min)		Flexture strength (MPa)		Pressure-strength (MPa)	
							start	end	7 days	28 days	7 days	28 days
96	0	4	2.3	3.10	3200	23.5	125	170	6.3	8.2	38.4	54.8
86	10	4	0.9	3.08	3180	24.5	165	220	6.6	8.2	42.0	56.0
76	20	4	1.3	3.04	3360	26.0	185	240	6.1	8.0	37.6	52.1
66	30	4	0.4	3.02	3470	25.0	190	230	5.9	7.1	31.2	48.3
56	40	4	0.3	2.95	3150	24.5	195	270	4.2	6.8	24.5	43.1
46	50	4	1.2	2.92	3170	22.5	235	310	2.9	5.4	17.5	33.9

Table 7. Characteristics of cement with addition of ashes from TEPS Tuzla

Clinker (%)	Ashes (%)	Plaster (%)	R009 (%)	Specific weight (g/cm³)	Specific surface (cm²/g)	Standard consistency (%)	Binding (min)		Flexture strength (MPa)		Pressure strength (MPa)	
							start	end	7 days	28 days	7 days	28 days
96	0	4	2.3	3.10	3200	23.50	125	170	6.3	8.2	38.4	54.8
86	10	4	3.9	3.00	3240	30.40	205	255	3.6	7.2	21.4	52.4
76	20	4	4.0	2.88	3200	32.10	230	280	3.4	6.2	19.3	43.5
66	30	4	4.2	2.77	3280	34.50	250	320	2.8	5.5	16.6	35.3
56	40	4	4.4	2.55	3050	36.60	280	340	2.4	5.0	12.7	29.8
46	50	4	4.6	2.40	3180	38.25	310	360	1.3	2.8	8.6	17.0

CONCLUSIONS

Based on the results of performed tests, the following conclusions can be elaborated:

- Both fly ashes by their chemical composition fall into the category of ashes with a high content of CaO, i.e. in calcium ashes according to BAS EN 197-1 (Ref. 4) and according to the American standard ASTM C 618. The ash from TEPS Kakanj has significantly higher contents of CaO, and also lower SiO_2 content in relation to the ash from TEPS Tuzla.
- The ash from TEPS Kakanj has several favourable characteristics in terms of use in the cement industry, which are: a high proportion of amorphous phase which amounts to above 50%, low non-burned carbon content, low content of free CaO and a very high proportion of particles of diameter below 20 μm. Mean particle diameter of ashes from TEPS Tuzla is 106 μm while for the ashes from TE Kakanj it is 7.86 μm.
- Regardless of the content fly ash in cement, the start time of binding with all cements is longer than 60 min, which is a condition prescribed with the standard BAS EN 197-1 (Ref. 4). The start time of binding is extended with increasing content fly ash in cement, which suggests that the reactivity of cement decreases with increasing ash content. The binding time is longer for the cement with addition of ash from TEPS Tuzla.
- By testing the constancy of volume[5] in function of the content of fly ash in cement, it can be concluded that all cements (0–50% ash) have a very small expansion, which is far below the allowable values prescribed with the standard BAS EN 197-1 (10 mm). This feature is one of the most important in terms of durability of cement composites. The reason for the very small expansion of cement with the addition of the ashes is that the fly ashes from both power plants have very low content of free CaO.
- Related to the development of strenghts of samples, we see that in the first 28 days of hydration, the cement without addition of ash has greater pressure strength than the cement with the addition of ash. After 7 days of hydration, the cement with addition of 10% ash from TEPS Kakanj (PC10) has a 9.38% higher pressure strength than the reference cement (PC0). Other cement samples with the addition of ashes from TEPS Kakanj have less strength than PC0 that reduces with the ash content. So, the samples PC50 has a pressure strength that is about 55% less than the strength of the reference sample PC0. All cements with addition of ashes from TEPS Tuzla have less pressure strength than the reference cement (PC0), and decreases with the content of the ashes so that the cement with the addition of 50% ash from TEPS Tuzla has for about 77% less pressure strength.
- After 28 days of hydration the difference between the strength of the cement samples with fly ash and reference cement sample decreases. The sample with addition of 10% ash from TEPS Kakanj has even greater pressure strength than

the reference cement. Generally speaking, the strength of cement with addition of ash is reduced significantly but only in the first 28 days of hydration. The cements with the addition of ashes from TEPS Tuzla have less strength in comparison to the same cement with addition of ashes from TEPS Kakanj.

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