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Influence of Fly Ash on The Grindability of Electrothermophosphorus Slag

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ABSTRACT

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Slag-alkali binders are an alternative to Portland cement. The main energy-intensive process in the technology of producing slag-alkali binders is separate or joint grinding of aluminosilicate components. The results of joint grinding of electrothermophosphorus slag with highly dispersed fly ash in a ball mill are presented.

Keywords : Electrothermophosphorus Slag, Fly Ash, Ball Mill, Grinding, Slag-Alkali Binders.

I. INTRODUCTION

Slag-alkali binders have been extensively investigated as a potential replacement for conventional Portland cement and concrete based on it to minimize CO_2 emissions from the production and disposal of solid waste from the chemical industry [1-3]. World cement production is about 4.2 billion tons, and the production of 1 ton of conventional Portland cement emits about 900 kg of CO_2 [4]. It turned out that slag-alkali binders are not only comparable with Portland cement [5], but also exceed in a number of physical-mechanical and physical-chemical properties.

The use of slag-alkali binders can reduce CO_2 emissions by up to 80% compared to Portland cement materials through the use of granulated slag, fly ash, etc. [4]. Another feature of slag-alkali binders is [31] that these technologies are less energy-consuming based on fly ash and granulated slag, since these industrial wastes have already undergone thermal treatment in the process of formation.

Of great interest are granulated blast furnace slags [6-9] and fly ash [10-13], which are potential aluminosilicate raw components in the production of slag-alkali binders [14-16]. Before use, the granulated slags are ground in mills to the required fineness of grinding. The main advantage of fly ash in comparison with other raw materials is the significant proportion in its composition of glassy phases of aluminosilicate composition and high dispersibility, which in most cases makes it possible to use them in their original state.

In some research results it was noted [17-21] that fly ash consists of many amorphous microparticles of spherical shape. These microspheres are three to ten times stronger than most hollow glass microspheres. Unlike glass spheres, microspheres have a higher compressive strength due to their stronger shell. The compressive strength is 150-280 kg/cm^2 [22]. Along with hollow spheroids in fly ash there are also porous formations. The total proportion of both can amount to 80-90 % of TPP fly ash volume

[23,24]. A possible solution for additional activation of fly ash can be separate or co-milling in a mill [36].

There are also scientific studies on the combined use of granulated blast furnace slag with fly ash [25]. In this study, an attempt was made to improve the properties of fly ash based binder paste by incorporating ground granulated blast furnace slag in different percentages.

In addition to granulated blast furnace slag, there are also electrothermophosphorus (ETP) slags formed at high temperatures [26]. Many researches have been devoted to the production and development of slag-alkali binders based on granulated ETP slag [27,28,32].

The distinctive aspect of making slag-alkali binders is not only that solid waste is used as a mineral component, but also that alkaline solutions of Na and K are used for mixing. The most commonly used alkaline activators are a mixture of sodium or potassium hydroxide (NaOH, KOH) with sodium ($nSiO_2 \cdot Na_2O$) or potassium glass ($nSiO_2 \cdot K_2O$) [29-31].

The main energy-consuming process in obtaining these binders is grinding the components in the mill in a joint or separate form [33-35].

In consequence of this, this work was devoted to the study of joint milling, granulated ETP slag with fly ash in a ball mill.

II. METHODS AND MATERIAL

Raw materials. Chemical composition of ETP slags in % by weight: SiO_2 - 34,0-45,0; Al_2O_3 - 1,07-3,29; CaO - 44,7-50,0; MgO - 0,91-4,38; F - up to 3; P_2O_5 - up to 2,5. In the granular form contain 95-98% glass. The crystalline phase is represented by calcite, quartz, and pseudo-vollastonite.

Chemical composition of fly ash from Angren TPP in % by mass: SiO_2 - 52,2-64,3; Al_2O_3 - 23,5-29,0; Fe_2O_3 - 6,0-10,0; CaO - 2,2-5,8; MgO - 1,0-2,0; R_2O - 1,0-2,3; unburnt coal -12,0-16,0. The mineral composition includes vitreous phases as well as crystalline constituents such as various modifications of quartz (0.425; 0.334; 0.246; 0.228; 0.223; 0.213; 0.1981; 0.1817; 0.1675; 0.1542; 0.1455; 0.1384; 0.1373 nm), hematite (0.368; 0.271; 0.252; 0.220; 0.208; 0.1841; 0.1698; 0.1596; 0.1486 nm), anhydrite (0.387; 0.350 0.313; 0.285; 0.233; 0.221; 0.220; 0.208; 0.201; 0.1941; 0.1877; 0.1750; 0.1648 nm), hydrosilica (1.005; 0.498; 0.446; 0.258 nm), etc.

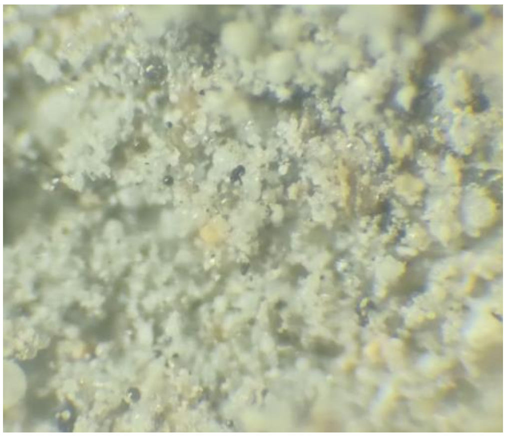

Fig. 1. Macro- and microphotographs of fly ash (x 120 times)

Fig. 2. Macro- and microphotographs of granulated ETP slag (x 120 times)

Research Methods. Grinding was carried out in a laboratory drum ball mill MBL-1. Steel balls and cones were used as grinding bodies. The duration of grinding was 75 minutes. The mass loaded into the mill in each case was 2 kg and was constant regardless of the composition of the mixture of fly ash and granulated ETP slag.

Estimation of fineness was carried out according to specific surface and residue on sieve No. 008. In addition, indicators of bulk density, the average diameter of grains and intergranular hollowness of fine grinding mixtures were determined. Specific surface, average grain diameter and intergranular hollowness were determined using PSX-11A device.

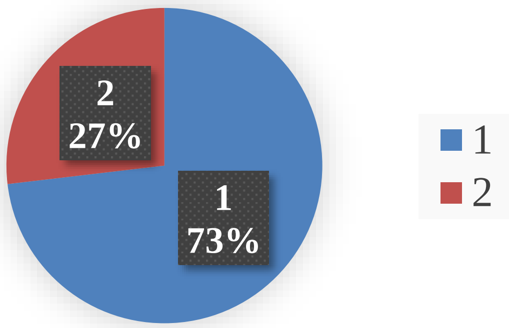

Fig. 3. Grinding load of the mill: 1-cone; 2-ball

III. Results And Discussion

Studies on the grindability of ETP slag in a ball mill were conducted beforehand. As can be seen from the results (Tab. 1) with increasing duration of grinding of ETP slag, the indices of residual quantity on sieve No. 008, bulk density and average diameter of grains decrease. At the same time the values of specific surface and intergranular hollowness increase in value.

Table 1: Characteristics of the grindability of ETP slag

No.	Grinding time, min	Residue on sieve No. 008, %	Specific surface, cm²/g	Bulk density, g/cm³	Average grain diameter, μm	Intergranular hollowness
1	45	20,4	1967	1,27	10,9	0,48
2	60	7,3	2611	1,19	8,2	0,52
3	75	4,4	3344	1,13	6,4	0,54

The specific surface area of 3000 cm^2/g is achieved with a grinding time of 70 minutes. A grinding time of 60 minutes is sufficient for the residue on sieve No. 008 (Fig. 4).

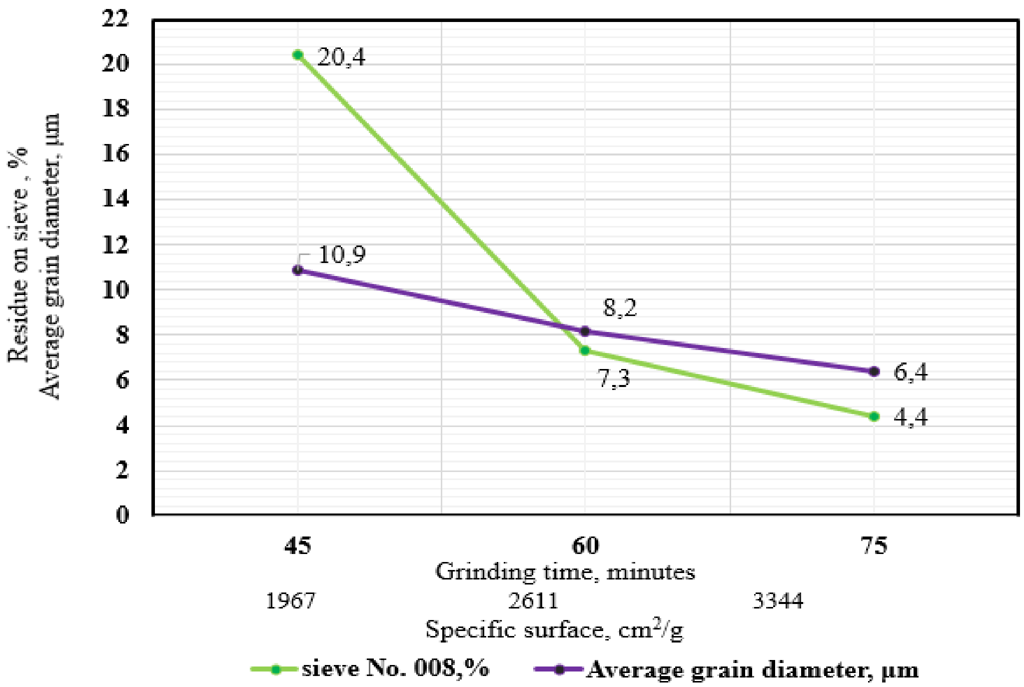

Fig.4. Kinetics of change in the residue on the sieve No. 008 and the average grain diameter from the specific surface of ETP slag

The increase in intergranular hollowness and decrease in bulk density indicate that the volume of the ground material increases with increasing grinding duration while the volume of the grinding charge remains constant (Fig. 5).

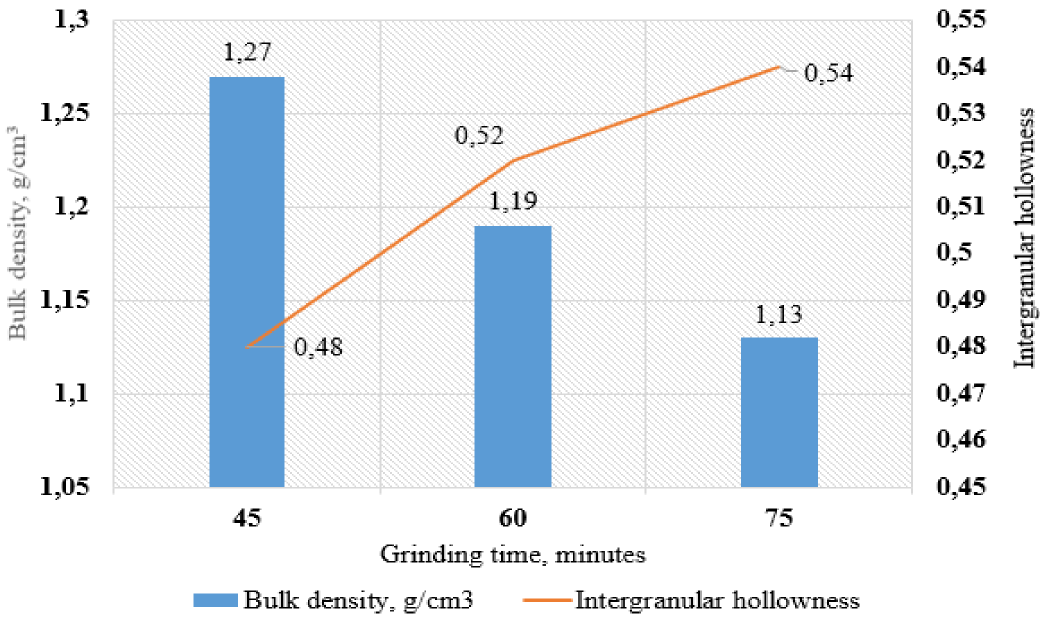

Fig.5. Kinetics of changes in bulk density and intergranular voids from the specific surface of ETP slag

Secondary parameters of milled slag can be used as additional criteria for assessing the fineness of grinding. They provide a more complete picture of the grinding process and increase the reliability of the results in terms of the specific surface area and the residue on the sieve. These criteria can also be successfully applied to determine the fineness of other materials such as cement, gypsum, lime, etc.

Subsequently a partial substitution of ETP with fly ash was carried out. The variation interval was 15 % of the total mass of the milled material. As it turned out, with the increase of the amount of fly ash in the compositions there was an increase of the specific surface and a decrease of the residue on sieve No. 008, average grain diameter, bulk density respectively (Tab.2).

Table 2. Physical characteristics of milling products

No.	Ratio of components, %		Specific surface, cm^2/g	Residue on sieve No. 008, %	Average grain diameter, μm	Intergranular hollowness	Bulk density, g/cm^3
	ETP slag	Fly ash					
1	85	15	4900	0,40	4,4	0,48	0,89
2	70	30	7236	0,64	3,0	0,49	0,82
3	55	45	8905	1,80	2,4	0,48	0,79
4	40	60	10039	1,48	2,1	0,48	0,73
5	25	75	12232	1,94	1,8	0,53	0,67

Visual inspection of the residue on the sieve No. 008 showed that the residue consists of glassy grains related to ETP slag. At the content of fly ash 45 % and more the mixture adheres to the walls of the mill and the surface of grinding bodies. Intergranular hollowness in mixtures with 15-60% fly ash content was stably 0,48-0,49. At the same time the bulk density tended to decrease, indicating the influence of not only the intergranular voids, but also the ratio and the granulometry of the components.

Fig. 6. Photos taken at the opening of the mill and after discharging the fine grinded mixture of ETP slag with fly ash

IV.CONCLUSION

Thus the possibility was established to use secondary criteria for assessing the grinding fineness in parallel with the traditional ones. These criteria complement the picture of grinding, increase the reliability of the obtained results and give an opportunity to strengthen the control of the technological process in production.

A positive effect of fly ash on the grinding of ETP slag was established. The more fly ash is in composition, the higher values of specific surface area and the lower values of average particle diameter and bulk density are. Irrespective of the percentage of replacement the residue on the sieve No. 008 does not exceed 2%.

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