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Part 3

ASH AND SLAG HANDLING

3.4. Beneficiation and ash management

3.4.2. Improvement of the building-technical properties of ash-and-slag materials from heat power generation

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ABSTRACT

Possible trends for improvement of the building-technical properties of dry ash characteristics formed as a result of solid fuel combustion at thermal power stations are presented. The results of application of different ash and slag benefication technologies to widen the trends and increase the volumes of their use in the construction materials and products are given.

INTRODUCTION

Ash-and-slag materials due to the variety of properties of power coals and other solid fuel and combustion conditions as well as different ways of their collecting and removing have different chemical and mineralogical composition, particle size distribution, chemical activity and melting temperature. In accordance with RD 34.09.603–88 by chemical composition ash-and-slag can be divided into acid and main groups; by content of combustibles − ash-and-slag with low, middle and high content of combustibles, (loss on ignition below 5, from 5 to 10 and more than 10 % accordingly); by particle size distribution –fine, middle and large (specific surface less than 150, from 150 to 300 and more than 300 m^2/kg accordingly); by melting temperature – low, middle and high (melting temperature below 1250, from 1250 to 1450 and more than 1450 ºC accordingly) [1].

The main characteristics for estimating a possibility of using ash-and-slag materials in production of building and construction materials are chemical composition, content of combustibles and free calcium oxide, specific surface, and melting temperature. Additional characteristics of ash and slag are humidity, grain structure, bulk density, and content of glassy particles in fly ash. On the other hand, suitability of ash and slag as the main raw material for production of construction materials is determined, before all, by a lack or limited content of harmful components which deteriorate physical-mechanical and operational-technical properties of products or complicating technological production processes and limiting the application range.

Fly ash, slag and ash-and-slag mixture produced from solid fuel combustion can be only used, if their properties meet technical standard requirements. So, only certified fly-ash meeting requirements of the GOST 25818–91 standard can be used in concrete. Fly ash which doesn't meet this or that standard can be used for other purposes if it meets the necessary requirements or can be stored at dumps. From the above information it should be pointed out that the quality of ash and slag recycled is strictly regulated. At the same time combustion modes at thermal power station (TPSs) do not always contribute in producing ash and slag of the «standard set» of characteristics and properties. Due to this reason ash or slag benefication should be considered as an ordinary operation choosing ash and slag treatment technology at TPSs.

At present benefication of ash and slag by a number of important parameters e.g. removal of hydrogen excess or particle size increasing is not regulated. At the same time in the European standard EN 450–2005 «Fly ash for concrete» requirements for composition and properties of the beneficiated fly ash are established.

In some European countries exist plants for fly ash benefication aiming to improve its properties due to separation of the certain fractions, unburned carbon separation, mixing, activation and etc. In Germany by means of air classification fine fractions of the feed ash with the size to 10 or 20 microns are separated and added into concrete, plastics and paints for improving its properties. To meet season's demand in dry fly ash installations for drying the disposed ash and slag mixtures are used in Germany and France. In Great Britain and Germany technologies for separating cenospheres from fly ash are applied. Cenospheres can be used in concrete or as paint, plastics, paper fillers, and other materials, unburned carbon - as solid fuel, magnetite is used in thermoplastics, fine and coarse ash fractions – for production of construction materials. Possible directions of improving building-technical properties of dry fly ashes from thermal power stations are presented below.

1. GRINDING

Fly ash particle size influences both ash portland cement properties and performance of concrete made from it. Conducting research L.Y. Goldstein [2] established that replacing 30 % of cement (specific surface of 320 m²/kg) with acid fine fly ash with specific surface of 650 and 1050 m²/kg, formed at additional grinding in the crusher, flowability of mortar mixture is decreasing but cement strength is increasing (see Table 1) [2]. By this, cement with fly ash addition, ground to specific surface of 1050 m²/kg, has compressive strength approximately equal to the corresponding index for cement without any addition after 28 days of hardening. However, in a later period of hardening cement with addition of fly ash having high specific surface, is getting 20 % higher strength than cement without any additions. High initial specific surface of ash particles results in elimination of additional expenses for their aftergrinding to apply in technologies of building materials manufacture traditionally based on fine raw materials usage. However, starting such technological lines, units for receiving and primary processing of the natural lump raw materials, are commonly set. As a result of this circumstance, forming dust from the lump in the working productions causes the definite difficulties connected both with adaptation of the equipment to dust raw material, and the necessity of fulfillment of certain dedusting operations in the technological processes.

Table 1. **Influence of fly ash specific surface and duration of hardening on portland cement strength**

Portland cement	Specific surface of fly ash, m²/kg	Changing of strength on compression, %			
		7 days	28 days	90 days	180 days
Without fly ash	–	64	100	114	134
With 30 % of fly ash addition	240 650 1050	46 51 56	77 89 98	112 133 133	124 144 147

2. AIR CLASSIFICATION

For studying the influence of various ash fractions on cement stone durability, fly ash, selected from dry ash discharge installation at the Reftinskaya State District Power Station, was subjected to fractionating on multiserial centrifugal qualifier. Four ash fractions (conditionally divided by the boundary size of particles 10 and 60 microns), with different quantity and particle size distribution, were received. The fine fraction has been presented by particles with the size less than 10 microns making more than 90 %. Ash particles with the size more than 60 microns have the highest density, particles less than 10 microns – the lowest density.

Besides, fine ash fraction has the increased unburned carbon content (6 %), and in the ash fraction from 10 to 60 microns it was absent.

It is established that the original ash and its fractions increase water requirement of ash portland cement, reduce density and durability of cement stone of water hardening especially considerably at its addition in the quantity of 30 % of the cement weight. However, after 1 day of steaming the cement stone with addition of the original ash and its fractions of the size less than 10 and more than 10 microns has higher durability in comparison with the cement without ash (Table 2).

Table 2. **Influence of ash fractions on physic and mechanical properties of the cement stone**

Ashes test	Ash quantity, mass. %	W/C	Density of the cement stone, kg/m^3	Strength at compression, MPa			
				Normal hardening		After steaming	
				3 days	28 days	1 day	28 day
Portland cement	0	0,27	2320	42,3	61,6	39,7	67,7
Original ash	15 30	0,34 0,46	2160 1990	37,7 20,9	52,3 34,4	44,9 36,1	71,1 49,4
Fraction > 60 microns	15 30	0,29 0,36	2270 2040	36,1 33,3	45,7 44,8	39,8 29,5	55,0 41,5
Fraction 10…60 microns	15 30	0,31 0,44	1850 1730	27,8 22,1	40,2 26,6	– –	– –
Fraction < 10 microns	15 30	0,37 0,47	2280 2130	27,9 24,4	42,9 34,9	44,1 36,1	60,0 57,3
Fraction > 10 microns	15 30	0,33 0,47	2150 1970	30,8 20,1	46,1 32,0	41,3 30,1	60,4 54,9

3. DECREASE IN COMBUSTIBLES

The essential factor, limiting application of fly ash in construction, is residual carbon in its structure, which is estimated, as a rule, by loss on ignition. Negative influence of the coke residue in ash is shown in decrease in durability of the cement ash stone due to absorption of calcium hydroxide by carbon, formed at cement hydration, that worsens a phase composition of the calcium hydrosilicates formed in the cement.

The strongest impact of this factor is seen at consideration of issues concerning processing of ash from Kuznetsky, Donetsky, Vorkutinsky and other coals with the small volatiles content at traditional pulverized burning. For these ashes loss on ignition change from 10 to 25 %, and sometimes can reach 35…40 %. It is possible to assert that on the majority of thermal power stations there are certain technical facilities for reduction of carbon loss. It is established that, as a rule, there is carbon in fine and coarse particles of about 0,5…1 mm. Presence of coarse ash particles having the unburned carbon follows from the non-optimal degree of particle fineness of coal at thermal power plants since for the full burning of large fractions of fuel more time is required than time of their staying in the combustion zone of the furnace. We believe that providing with the required degree of coal particle (maintaining grinding characteristics of the crushers, modernization of coal mill separators, and etc.) allows reducing the coke rest surplus in ash. An alternative to this option is creation of technological lines for separation of ash into two fraction groups with different carbon content. The possible unburned carbon separation technology is presented in [3]. In the world practice the technology for separation of the residue carbon from ash developed by Separation Technologies Company is widely enough applied [4].

4. GRANULATION

Granulation is one of effective ways for improvement of the consumer properties ash and slag materials [5]. It is more often used in technologies of producing light fillers for concrete [6]. Granulation allows to essentially simplify the use of fly ash as a substitute of natural raw materials. It allows to eliminate application of the expensive special techniques for ash discharge, transportation and production of various commodity output in traditional technologies. It is rather important that the granulated ash, in essence, combines advantages of the lump materials and original ash as the ash granules made without fired technologies, are usually easily crushed at the joint grinding with other components.

Granulation of high calcium ashes from brown coals of Kansko-Achinsky basin is especially effective. It is established that such ashes are well granulated, the output of granules of the size less than 5 mm is below 5 %, fraction of the size of 10…20 mm was in the range of 77…85 %, and their point durability made to 30 N/granule. The greatest strength had granules made of coal fly ash in the boilers with dry bottom furnace (Table 3). At disposing of the granulated ashes at the dump their consumer properties are preserved (Table 4) and harmful impact of ash and slag removal systems of thermal power plants on environment is significantly reduced.

Table 3. **Properties of ash granules depending on a method of brown coal combustion**

Indicators	Method of fuel combustion		
	Slag-tap boilers	Dry bottom boilers	FBC
Water requirement of ash, %	18…28	30…36	40…70
Bulk density, kg/m^3	900…1200	800…1100	700…1000
Average density, kg/m^3	1560…1970	1090…1460	1080…1320
Quantity of granules release from height of 0,3 m	5…15	4…6	3…15
Maximum height of release, m	0,8…1,5	1,0…1,5	0,5…1,0
Durability at compression after 1 day of hardening, N/granule	10…100	60…120	5…50

Table 4. **Change of ash granules properties at atmospheric storage within 4 months**

Characteristic, unit	Value		Change, %
	Initial	After storage	
Average density, kg/m^3	1350	1655	+22,6
Bulk density, kg/m^3	850	998	+17,4
Water absorption, %	28	11	−60,6
Compressive strength in the cylinder, MPa	1,43	3,36	+134,9
LOI, %	17,3	24,5	+41,6

The mentioned advantages of the granulated ash do not expel the possible piling of high calcium dry ash in the moistened condition or other ways, however it should be taken into account that the consumer properties of the palletized ashes are worse, than of the granulated ones. In any case, selecting the technology of ash benefication it's needed to consider the number of the following main criteria:

- conformity to requirements of ecological certificates;
- stable phase and chemical compositions of ash and slag, humidity, stability against caking and freezing, and also no dusting;
- optimum content of useful components, for example, calcium oxides in the form of lime or clinker minerals;
- aggregate conditions suitable for further handling;
- constant ash and slag properties at transportation;
- liability of ash and slag demand level to seasonal fluctuations, and etc.

CONCLUSION

By the example of ashes from power coals the possible directions of improving building-technical properties of ash and slag materials from thermal power stations are considered. Effectiveness of ash and slag materials usage depends both on consumer properties and directions of ash and slag use in construction materials and products.

REFERENCES

1. **РД 34.9.603−88.** Методические указания по организации контроля состава и свойств золы и шлаков, отпускаемых потребителям тепловыми электростанциями. Введ. 01.01.1989. М.: ВТИ, 1988.
2. **Гольдштейн Л.Я.**, Штейерт Н.П. Использование топливных зол и шлаков при производстве цемента. Л.: Стройиздат, 1977. 152 с.
3. **Долганов Е.А.**, Уфимцев В.М., Канусик Ю.П. Пневматическое кондиционирование зол теплоэнергетики. Комплексное использование минерального сырья, 1990. №12. С. 49−52.
4. **Биттнер Д.Д.**, Газиоровски С.А., Левандовски В. Технология сепарации фирмы STI для выделения мехнедожога из летучей золы. Межд. научн. практ. семинар «Золошлаки ТЭС: удаление, транспорт, переработка, складирование». М.: Издательский дом МЭИ, 2009. С. 80–86.
5. **Вишня Б.Л.**, Уфимцев В.М., Капустин Ф.Л. Перспективные технологии удаления, складирования и использования золошлаков ТЭС. Екатеринбург: УГТУ-УПИ, 2006. 156 с.
6. **Элинзон М.П.** Производство искусственных пористых заполнителей. М.: Стройиздат, 1974. 256 с.