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Ash and Slag Waste as a Secondary Raw Material

P.V.Menshov[a]*, Y.V.Khlupin[a], O.I.Nalesnik[a], A.V.Makarovskikh[a]

[a]National Research Tomsk Polytechnic University, Lenina ave. 30, Tomsk 634050, Russia

Abstract

In the process of industrial corporation activities a lot of waste, which pollutes the atmosphere, is generated, for example ash and slag. In Tomsk region, by estimates, ash stores occupy about 600 hectares, which contain about 25 million tons by weight. In Russian thermal power-stations ash disposal areas there are about 1.3 billion tons of ash, and only 10% of it is used. That is why this problem is topical enough. In this paper the scheme of producing ash ceramic bricks and complex ash and slag waste processing is shown. Besides, profitability of the project is presented.

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Keywords: Ash, slag, ashstore, waste processing, waste-free production, investment project.

1. Introduction

In the process of energy corporation activities a lot of ash waste, which pollutes the atmosphere, is generated. As a result we have a lot of occupied territories. Effective processing of ash from energetic corporations working on coal will help to reduce negative influence on the environment and make better economic indexes of corporation. In general, ash is widely used in different productions and has a big market potential. There are

* Pavel Menshov. Tel.: +7-952-893-75-21; fax: +7-382-256-3865.
E-mail address: pvm8@tpu.ru

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available technologies of ash utilization; some of them are commercially widely used. Additionally, in many countries interesting methods and techniques are being developed, and obviously some of them have a huge potential. At this stage our main aim is to create a complex scheme of ash and slag processing.

In Russian thermal power-stations ash disposal areas there are about 1.3 billion tons of ash. Annually power stations produce up to 30 million tons but only 3 million tons (10%) are recycled. Production of building materials (3-5%) is included in the process. According to expert estimates, the cost of 1 ton of ash and slag waste content ranges from 200 to 500 roubles or 5-7% of the cost of electricity and heat production on a coal power station. Reconstruction investments for ash dump utilization may reach 1 billion roubles in cost. Within 3-5 years the overflow of ash and slag waste will assume mass proportions, and this process has already begun.

Tomsk is not an exception. According to the open Internet resources, there are three ash dumps:

1. Old ash dumps at “Power Station”-2 that was put into operation in 1973 and located in the Ushaika valley. Currently, it doesn’t operate. There are about 450 tons of ash waste on 35.8 hectares.
2. A new ash dump located in the valley of Malaya Kirgizska (Tomsk Severny station) was put into operation in 1986 and now in its area of 60.9 hectares there are about 1251 tons of ash waste (the information dated to 2003).
3. In Seversk near Chernilshiki village in the floodplain of Tom River, there are over 500 hectares of ash and slag, which constitute 24 million tons.

2. Use of ash and slag waste

Ash and slag waste (ASW) is a raw material for building material industry, which may successfully compete in a raw material market effectively substituting natural resources (GOST 25592-91, GOST 25818-91, TU 34-70-10347-81, GOST 530-95, GOST 25485-82, GOST 21520-89 and others). The use of ASW reduces the cost of building materials production (cement, dry mortar, concrete, mortar, concrete wall and foam concrete blocks, bricks, paving slabs, and other products) by 15-30 %.

The use of ASW is very diverse: for example backfilling mines, soil consolidation, creating mounds over landfills, vertical sealing walls to prevent seepage of wastewater from the landfill, soundproofing walls, agriculture, etc.

Examples can be found abroad. So, in Germany and Denmark in the building materials industry it is used nearly 100% of the annual output of ASW (in Germany ash and slag store is prohibited in law). Up to 70% of the annual output of ASW is used in the USA, the UK, Poland, China and other countries. Changes in the law of India in 1999, and then in 2003 led to increase in the volume of ASW utilization in the country from 29.6% (2003-2004) to 53% of annual output (2007-2008), which is about 70 million tons per year.

Ash and slag consist of many useful components, which may be used in different areas of human activity. In this paper recycling and obtaining useful components from ash are focused on. Ash contains a lot of useful components: aluminosilicate microspheres (1.2%), magnetite (5.9%), alumina (AL_2O_3 (20-27%)), silica (SiO_2 (49%)) or oxides of rare-earth metals (7%), which may be used in differently (Figure1). But slag is extracted at the first stage of complex processing and sent for slag stones production which has a wide application (Figure 2).

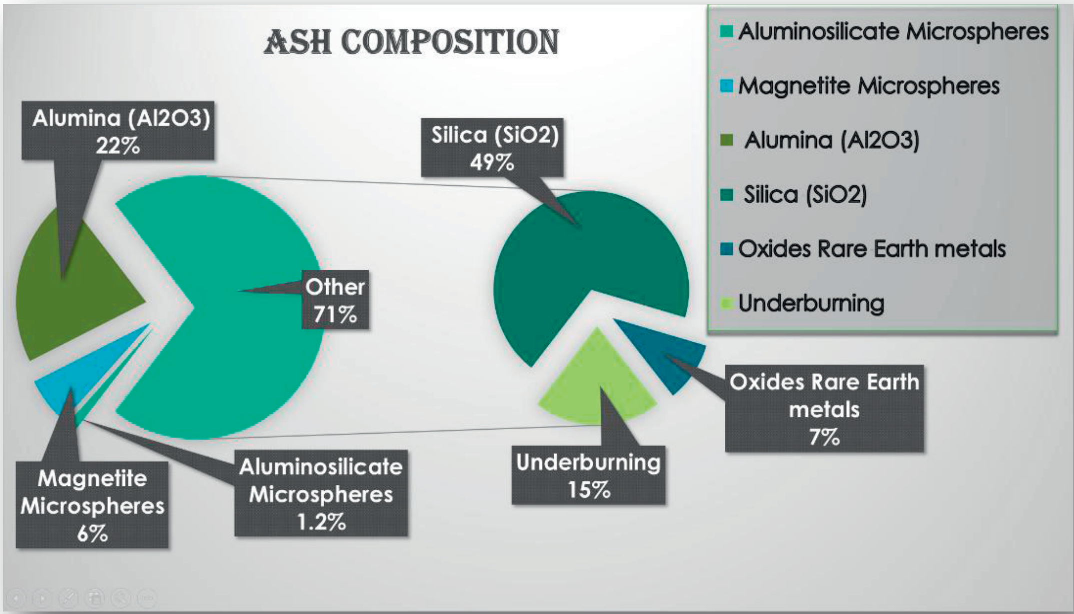

Fig.1. Ash components

3. Production of building blocks and expanded clay sand

In Seversk an effective method of coal disposal (production of wall materials with high consumer properties: brick, road stone, bloating clay aggregate, etc. with the initial ash content of 99.9 %) has been developed by "SYTECO" and TPU specialists. This technology has been tested using ash from coal combustion of the Kuznetsk Basin in Seversk (thermal power station-1), Tomsk (power station-2), Ust-Kamenogorsk (hydroelectrical power station-1) and ash from coal combustion in the Ekibastuz Basin in Yekaterinburg (“Reftinskaya” power station).

As it can be seen in the scheme (Figure 2) the technology consists in full utilization of ASW. The principle of operation: ash goes directly to the magnetic separator, which in turn separates a magnetic fraction. Next, the small particles of slag and ash are separated from big ones by a vaporizer head. They go to the crusher and get into operation again. The small particles are mixed in a mixer with a binding agent. Then, the ash is formed into granules, and after that it is decided where to go: to the drying drum for obtaining expanded clay sand, or to the vibroshaper and dryer for obtaining forms of a final product.

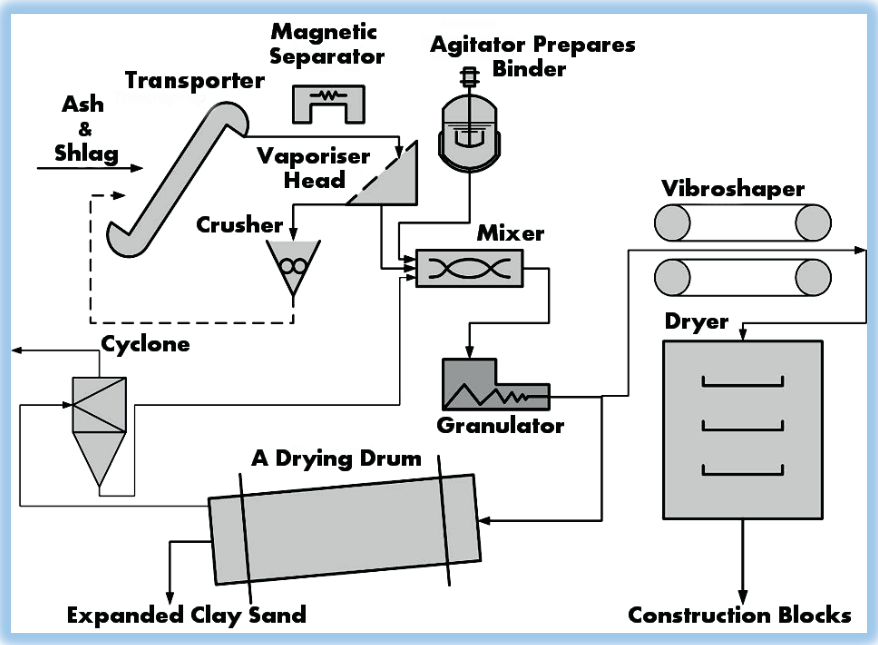

Figure 2. Flow sheet of building blocks and expanded clay sand production

Table 1. Characteristics of clay or expended clay brick production.

Characteristics	Units	Base technology	New technology
Weight	gram	2 900-3 200	2 100-2 600
Molding mixture humidity	weight, %	18-22	4-7
Density	g/cм³	1.6-2.0	1.18-1.40
Presence in the charge of fuel or combustible substances	weight, %	0, therefore ground coal or sawdust injected	9-11 of residual fuel
Heating rate	°C/min.	1.0 -1.5	not limited
Air drying	hours	least 48	None
Drying in the drying chamber	hours	least 24	None
Firing time	hours	least 36	max 6
Strength	kg /cm ² (MPa)	75-150 (7.5-15)	150-300 (15-30)
Frost-resistance	cycles	15-50	more than 50
Fuel consumption for firing of 1000 pcs. of conventional brick	kg	235 (plant №2, Tomsk)	93-160
Water absorption	weight, %	9-11	5-22
Thermal conductivity	w/m·K	0.45 – 0.5	0.3 – 0.34

The benefits of expanded clay brick production are presented below:

- Simplified firing conditions of the products due to addition of an inexpensive binder to the charge; without drying;
- Reduced duration of the heat cycle of an ash-ceramic brick from 36 to 6 hours;
- Reduced fuel consumption for firing of one item of ash ceramic bricks (1.5-2.5 times less than firing of clay bricks).

An ash-ceramic brick exceeds a clay brick by such parameters as strength, frost resistance, chemical resistance, etc.

We have compared characteristics of clay and ash blocks. As a clay, material agloporite is used. It is a lightweight aggregate concrete in the form of crushed stone or gravel, used as a construction-insulation material. As it is shown in Table 2, thermal conductivity in ash blocks is less than in clay ones, as well as many other characteristics like the rate of heating, firing time, frost-resistance and etc.

Table 2. Characteristics of ash blocks and agloporite

Agloporite		**Ash block**	
Fraction, mm	4 - 10	Dimensions in mm	400x200x300
Bulk density, kg/m^3	335	Volumetric weight, m^3	1 000-2 000
Volumetric weight, kg/m^3	550...800	Compressive strength, kg/cm^2	50-150
Compressive strength, MPa	1.2...1.4	Thermal conductivity	0.3-0.8
Water content, % by weight	0.5	Frost resistance of cycles	50
Thermal conductivity	0.11	Water absorption, %	40
Water absorption	25%	Shrinkage, % in mm/m	0
Fire resistance	Fireproof building material	Fire resistance	Fireproof building material

4. Complex processing

The principal scheme of ASW processing, divided into three stages with extraction of beneficial substances, has been developed including calculation of profit and costs for each stage.

As it can be seen from Figure 3, ash is promptly separated from slag. The slag goes to the serial module for producing ash ceramic bricks, and ash goes through the water-repellent agent, where is converted into granules. Then coke is separated in vaporizer head. In order to obtain consistency with the necessary properties screen product must again pass the stage of granulation in adder. In the mixer, ash is mixed with water for separating heavy fraction from light ones in hydrocyclone. A light fraction generally consists of microspheres, therefore, it goes through the centrifuge and, depending on its weight, gets into the bunker or mixer respectively. A heavy fraction goes through the magnetic separator, where a magnetic fraction is separated from ash in the bunker. The ash goes through the centrifuge and gets into the mixer. Where it can be mixed with water and undergoes a process of graining, after it should be either prillinged or granulated, and then processed weight, can be sold directly to the consumer or put into production of ash materials, for instance from prilling it goes into production of ashbricks, paving slabs or build-blend. Or after granulating it can be also sold or put into production agloporite, pavement, or HIC.

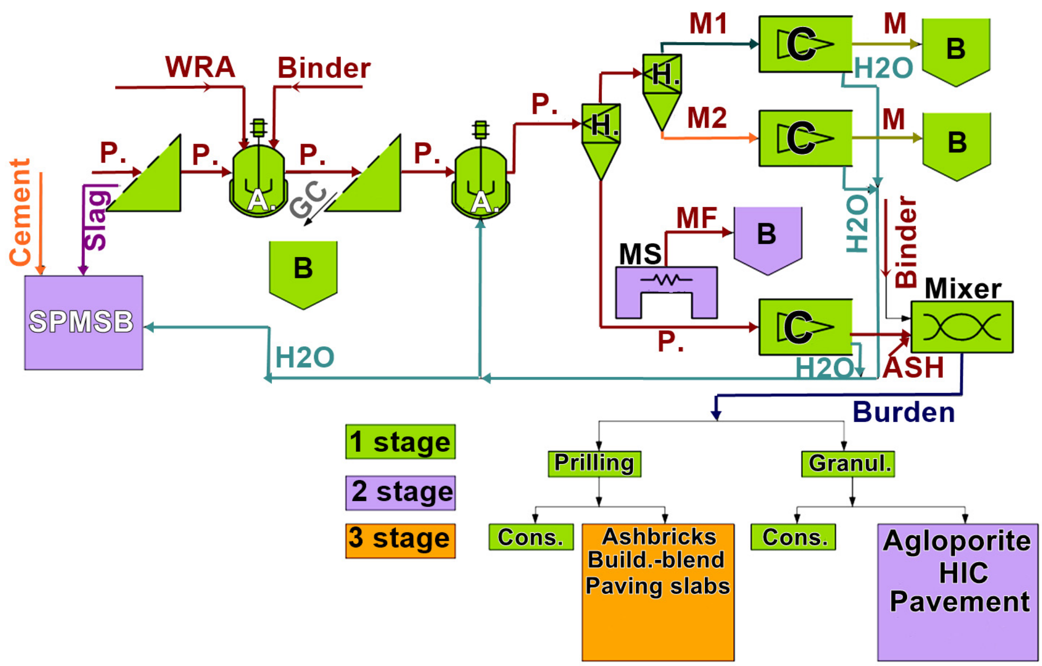

Figure 3. Complex processing with useful components extraction
Annotation to scheme for complex processing:
WRA – Water-Repellent agent; P. – Pulp; A- Adder; GS – Granular Coke; M1 – Microspheres with p<1; M2 – Microspheres with p>1;
M – Microspheres; H. – Hydro cyclone; C – Centrifuge; B – Bunker; MS – Magnetic Separator; MF – Magnetic Fraction;
SPSMB – Serial production module of Slag blocks;
Granul. – Granulation; Cons. – Consumer; Building – blends; HIC – Heat-Insulating Concrete.

5. Investment

On the base of complex processing of thermal power plant ASW of Seversk Chemical Combine the investment scheme has been developed. The purpose of the proposal is full utilization of current ASW dumping and gradual termination of stored ASW. There are some stages of investment.
First stage (124.5 million roubles) includes:

- ash store testing and putting it into operation;
- converting ASW into a technological form;
- extracting available products (magnetite, aluminosilicate microsphere, underburning).

Payback prediction of the first stage is about 2.5 years.

Table 3. First stage

Processing products	Indicators of the project						
	Extracting		Price of plant, mln. roubles			Operating costs mln.rbl	Payback years
	Thousand tones	Mln. roubles	Technology	Facilities	Infrastructure		
Aluminosilicate microsphere (glass	36	540	0	8	2.4	2.0	0.02

phase-80%, silica-up to 10%)							
Underburning (C: 88-98%, S: 0.5%)	12	16.8	0	9	0.6	2.3	0.6
Magnetite concentrate (Fe_3O_4), pure Fe-53-64%	9	13.5	0	13	0,9	3.0	1.1
Building slag of GOST (shredded and dried large fraction of ASW without further processing)	40	20	0	10	1,0	2.5	1.5
Granulated ash (additive for ashfoam blocks, bricks, dry mixes, etc.)	103	33	0	55	3	13.0	2.32
Total	200	623.3	0	95	7.9	21.6	2.5

Second stage (465.2 million roubles) is producing roasted agloporite, blocks and fillers. Payback prediction is about 2 years.

Table 4. Second stage

Processing products	Indicators of the project					
	Extracting		Price of plant, mln. roubles		Operating costs mln.rbl	Payback years
	Thousand tones	Mln. roubles	Facilities	Infrastructure		
Non-autoclave ash foam concrete blocks (with cement), thous. m^3	25	87	14	2.2	4.0	0.6
Granulated ash fillers and insulation	55	150	70	30	30	1.5
Buildings mixtures (cement additive), thous. m^3	30	126	60	40	35	1.8
Agloporite (roasted expanded clay)	150	200	90	50	109	1.5
Total	260	563	234	122.2	109	2.0

Third stage (822.0 million roubles) is producing ash-bricks, ferroalloy and alumina. Payback - about 1.5 year.

Table 5. Third stage

Processing products	Indicators of the project						
	Extracting		Price of plant, mln. roubles			Operating costs mln.rbl	Payback years
	Thousand tones	Mln. roubles	Technology	Facilities	Infrastructure		
Alumina (83%), for producing ferroalloy	10	150	5	40	15	20	0.5
Ferrosilicate and ferroaluminium (FSA-25), deoxidizer for ferrous metallurgy	30	750	30	450	70	110	1.2
Ashbricks of 99.9% of ash (35 mln. units per year)	60	123	2	117	87	50	2.8
Total	100	1023	37	607	85	130	1.5

The investments of the entire project are 1411.7 million roubles. All equipment is standard. Full processing volume is 560 thousand tons per year.

6. Conclusion

With a huge creative and technological potential, with innovative opportunities Tomsk region can and should turn an anthropogenic raw material like ash waste, collected for decades from thermal power plants, into high-quality products. By this it will provide restoration of land, filled with ash dumps, expanding urban areas and creating new jobs in manufacturing and construction areas.

The proposed idea of ASW utilization has been developed for Seversk thermal power plant, but it can be varied and used by other ones.

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