FLY ASH AS A COMPONENT OF CONSTRUCTION MATERIALSE

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Abstract: The issue of effectively utilizing fly ash is a global environmental problem that requires urgent attention and immediate action to resolve. Studies show that enormous volumes of fly ash are generated annually, yet only 25% of this waste is recycled. To address this alarming situation, efforts must focus on increasing its use across various industrial sectors. Promising applications of fly ash in construction, electronics, resource recovery, wastewater treatment, agriculture, and other industries require further research. Of particular interest is the use of fly ash in industrial processes. The physical, chemical, and mineralogical properties of fly ash—such as its morphology, specific surface area, porosity, and chemical composition—make it an ideal material for various technological processes. Expanding the use of fly ash in various industrial sectors and its application in processes will significantly increase its utilization rate and reduce its negative impact on the environment.

Keywords: fly ash; waste; brick; sintering; mechanical properties

Introduction

The annual increase in ash and slag waste amounts to approximately 1.5 million tons, with the area of land used for their disposal reaching about 20,000 hectares. The accumulation of ash dumps leads to a deterioration of the environmental situation in the surrounding area and the region as a whole. As a result of “dusting,” ash particles pollute the air, and the migration of components leads to soil and water contamination with heavy metal ions (copper, lead, cobalt, nickel, manganese, etc.) and toxic elements (arsenic, antimony, strontium, barium, etc.).

In this regard, finding effective methods for processing this waste with the potential for its further use in the production of building materials has become a pressing task. Such an approach allows for a reduction in the anthropogenic impact on the environment, as well as a decrease in costs for both waste storage and product manufacturing. The low rate of ash dump utilization is due to the limited research on ash and slag waste, resulting from its complex morphological, mineral, and elemental composition.

The use of recycled materials in the construction industry contributes to the development of high-tech enterprises capable of producing competitive materials using ash and slag waste. Such materials include dry construction mixes, high-strength cements, ash-mineral thermal insulation products, cellular concrete blocks, lime-ash bricks, and other types of products where ash and slag waste acts as a component that improves the performance characteristics of the products.

Due to their high chemical reactivity, ash dumps contribute to the contamination of atmospheric precipitation and meltwater with calcium hydroxide and heavy metal compounds. This leads to a disruption of the chemical and biological balance in adjacent water bodies and causes serious environmental consequences. In addition, large thermal power plants incur significant financial costs associated with transporting ash and slag waste to storage sites and constructing ash dumps. At the same time, these costs are constantly rising, as the price of land allocated for such facilities continues to increase. At the same time, these wastes constitute a man-made raw material that can be effectively utilized to meet societal needs. The construction industry is the largest consumer of various industrial wastes.

Construction is one of the most material-intensive sectors of the economy and, more than any other industry, offers vast opportunities for the efficient use of byproducts from large-scale manufacturing, including the fuel and energy sector, metallurgy, and other industries. Ash from thermal power plants is a cheap and virtually inexhaustible source of raw material that could become the primary raw material for the construction industry, since only the construction industry is capable of utilizing such a large volume of generated ash. Fly ash is a finely dispersed material consisting, as a rule, of particles ranging in size from fractions of a micron to 0.14 mm. It is produced as a result of burning solid fuel at thermal power plants and is captured by electrostatic precipitators; it is then collected in a dry state using an ash collector for industrial use, or sent to an ash dump along with water and slag. Fly ash is produced at thermal power plants that use pulverized coal. Some thermal power plants collect up to 2,000 tons of ash per day. The amount of ash can vary—from 30 to 300 grams per kilowatt-hour of electricity generated. Coarse ash (in small quantities) is collected at the bottom of industrial boiler furnaces, and the flue gas is then cleaned mechanically and, most importantly, using electrostatic precipitators, which ensure high flue gas cleaning efficiency. Dry ash is collected at a storage and homogenization site and then transferred to silos, from which it is typically transported in tankers (road, rail, or barge). To facilitate loading and unloading operations during transportation and storage, the ash is sometimes moistened with water (10–20%). It is sent either directly to the consumer or back to the furnace for reuse. Sometimes the ash is moistened with a large amount of water (30%), in which case it is transported as a slurry through pipelines and collected in settling tanks. In rare cases, ash is sent for sintering in cyclone-type boilers. It is then rapidly cooled in water, as in the granulation of blast furnace slag. This produces fused ash. The advantage of such ash is the almost complete absence of unburned material, but its particle size is much larger than that of fly ash (0.5–3 mm for fused ash, 1–200 μm for fly ash). Thermal power plants that process ash using this method are particularly widespread in Germany and the United States.

Currently, the development of the ceramic products industry is directly linked to the continuous modernization of existing technologies (processes), the development of new materials, the use of waste from local industries as raw and additive materials, and efforts to improve cost-efficiency and reduce the energy intensity of existing production facilities. The trend toward the depletion of natural resources for the production of wall ceramics has contributed to the identification of high-quality raw materials from waste generated by thermal power plants. Therefore, according to the authors, one of the promising directions is the use of fly ash from the combustion of bituminous coal at thermal power plants (TPPs) as one of the primary fuel-containing raw materials.

Today, technologies for manufacturing modern, high-quality building materials can be based on the use of multi-ton industrial waste, such as metallurgical slag and fly ash from TPPs. In general, ash can be used in three ways: – as an additive in building materials to replace part of the cement; – to replace part of the sand; – as an independent component. Ash waste generated during combustion at thermal power plants can be utilized in various ways, including in the production of building materials. The use of ash in various types of construction materials promotes chemical reactions and interactions that improve the properties of the resulting materials [2]. The ash produced after the combustion of solid fuel is captured using special electrostatic precipitators and is subsequently either collected by a special collector for industrial use in a dry state or sent to a landfill along with the slag and water produced during the process. The main parameters for classifying fly ash include its chemical composition, phase mineralogical composition, particle size distribution (sieve residue), and unburned carbon content (loss on ignition) [3].

The composition and structure of ash are influenced by factors such as:
– fuel type and morphological characteristics
– fineness of grinding;
– ash content of the fuel;
– temperature in the combustion zone;
– chemical composition of the fuel's mineral components;
– combustion time of particles in a given area.

Study of the possibilities of using fly ash for the production of ceramic bricks

Fly ash is one of the by products of thermal power plants, formed during fuel combustion. It is produced when flue gases are removed from the boiler furnace by ash collectors and consists of a gray or dark gray powder with a brownish tint similar to the color of cement, with a bulk density ranging from 0.7 to 1.2 g/cm³. CHP ash has a deformation onset temperature (change in interatomic distances) of 1200–1300 °C, a softening point of 1225–1340 °C, and a melting point of 1320–1460 °C. The melting range of the ash is 120–140°C. During fuel combustion, most of the mineral components are converted into fly ash, which is carried away by the flue gases [5]. To investigate the possibility of using industrial waste as a mineral powder in the production of ceramic bricks [1], fly ash from a thermal power plant was studied. The results of the chemical analysis of the fly ash and clay used in the study are presented in Tables 1 and 2, respectively.

Table 1. Chemical composition of clay

Oxide(%)	Al_2O_3	SiO_2	Na_2O	K_2O	CaO	FeO_3	MgO	SO_3
Clay	20.85	50.80	0.55	4.05	3.60	7.00	1.95	1.25

Table 2. Chemical composition of fly ash

Oxide(%)	Al_2O_3	SiO_2	Na_2O	K_2O	CaO	FeO_3	MgO	SO_3
Fly Ash	20.55	54.55	0.65	2.0	4.25	9.25	4.45	0.50

The table shows that fly ash consists mainly of SiO_2 and Al_2O_3, present primarily in the form of divalent and trivalent oxides, with CaO accounting for 4.25% of the total. In addition, the oxide composition also includes Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, SO_2, and others [4]. The ash particles have a distinct spherical shape and structure. Table 3 shows the particle size distribution of the materials used.

Table 3. Particle size distribution of the materials used

Particle Size (µm)	**Fly Ash %**	**Clay %**
<2	3	18
2-10	19	48
10-20	21	16
20-40	22	13
40-100	19	3
100>	16	2
TOTAL	100	100

When fly ash is used in construction, questions often arise regarding the radioactivity of this type of waste; however, compliance with the standard on the non-radioactivity of fly ash has been verified. Analyses conducted by the Department of State Sanitary and Epidemiological Surveillance on the specific effective activity of natural radionuclides in from thermal power plants show that, based on the content of natural radionuclides, the fly ash under study falls into Class II of construction materials and may be used in construction in accordance with GOST 30108-94 "Materials and Products".

The initial stage of the work involved the preparation of raw materials, during which the initial clay raw material and fly ash underwent grinding in a planetary mill. The prepared mixture was moistened with 15–20 ml of water. The samples were pressed using the semi-dry pressing method. The composite materials were obtained in the form of tablets and cylinders, which were pressed using a hydraulic press. After the pressing process, the resulting samples underwent natural drying; if necessary, the samples underwent artificial drying in an oven at up to 100°C. The next stage of this research was the sintering of the composite materials. The sintering process was conducted at 950, 1000, and 1100 °C. The sintering process lasted 10 hours with a 2-hour hold at the maximum sintering temperature.

After the firing process, the fired samples underwent the next stage of determining the physical and mechanical properties of the fired composite materials, during which the main physical and mechanical properties of the ceramic materials were measured under laboratory conditions. The results for the fired ceramic samples are presented in Table 4. As can be seen from Table 4, clay with a 100% content serves as the reference standard for samples with fly ash added. In the preparation of the experimental samples, the brick clay was ground in a roller mill with a 1 mm aperture and then sieved through a 1 mm mesh sieve. Ash was also obtained in the required amount and added to the mixture. To obtain comparative experimental results, samples were prepared in 6 different mixtures by mixing clay and ash in various proportions ranging from 0% to 100% (Table 4).

Table 4. Mixing ratios of experimental samples

Marking of samples	A	B	C	D	E	F
Clay	100	70	60	50	10	
Fly Ash		30	40	50	90	100

Results and Discussion.

The porosity values of the samples obtained were calculated in accordance with general standards. The porosity values obtained for the experimental samples, which were mixed, prepared, and fabricated in various weight ratios and sintered at 950, 1000, and 1100 °C, are shown in Figure 5. Accordingly, the porosity values at 950 °C range from 30.59% to 48.48%. The high porosity values at this temperature are due to insufficient sintering of the fired sample. At 1000 °C, the porosity values are relatively lower compared to 950 °C and reach their minimum value.

Figure 5. Porosity values (%) of samples at various temperatures

Marking of samples	950^0	1000^0	1100^0
A	41.64	41.27	19.49
B	30.59	29.67	21.81
C	34.89	37.37	26.88
D	37.19	37.98	34.18
E	43.61	43.78	30.98
F	48.48	44.57	33.08

It was determined that the porosity was 29.67%, with a maximum porosity value of 44.57%. At 1100 °C, the porosity values decreased significantly compared to other temperatures, ranging from a minimum of 19.49% to a maximum of 33.08%. Images obtained using a scanning electron microscope (SEM) show that at 1100 °C, a greater amount of glassy phase formed in the structure. It is assumed that the decrease in porosity values at 1100 °C is due to increased formation of the glassy phase and the closure of open pores. Similar results were observed in other studies.

Conclusions

Based on the above, it can be said that ash waste from thermal power plants is a unique material for use in various industries, including construction, metallurgy, agriculture, and so on, and that various types of products can be obtained and manufactured from the valuable components extracted from it. Furthermore, the introduction of thermal power plant waste into industrial circulation will not only reduce the volume of waste in existing ash dumps but also prevent its accumulation by avoiding the generation of new volumes and the creation of new storage sites for CHP plant waste. Incorporating fly ash into industrial processes will create a zero-waste production system and reduce the burden and environmental impact of the fuel and energy sector.

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UÇUCU KÜLÜN TİKİNTİ MATERİALLARININ KOMPONENTİ KİMİ İSTİFADƏSİ

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Xülasə: Uçucu külün səmərəli istifadəsi problemi qlobal ekoloji problemdir və onun həllinə təcili diqqət və dərhal tədbirlər tələb olunur. Tədqiqatlar göstərir ki, hər il böyük həcmdə uçucu kül əmələ gəlir, lakin bu tullantıların cəmi 25%-i təkrar emal olunur. Bu narahatedici vəziyyəti aradan qaldırmaq üçün onun müxtəlif sənaye sahələrində istifadəsinin artırılmasına diqqət yetirmək vacibdir. Tikinti, elektronika, resursların bərpası, tullantı suların təmizlənməsi, kənd təsərrüfatı və digər sahələrdə uçucu külün tətbiqi üçün perspektivli istiqamətlər daha ətraflı tədqiqat tələb edir. Sənaye proseslərində uçucu külünün istifadəsi xüsusilə maraq doğurur. Uçucu külünün morfologiyası, spesifik səth sahəsi, porozitə və kimyəvi tərkibi kimi fiziki, kimyəvi və mineraloji xüsusiyyətləri onu müxtəlif texnoloji proseslər üçün ideal material edir. Uçucu külünün müxtəlif sənaye sahələrində istifadəsinin genişləndirilməsi və proseslərdə tətbiqi onun istifadə səviyyəsini əhəmiyyətli dərəcədə artıracaq və ətraf mühitə mənfi təsirini azaldacaq.

Açar sözlər: uçucu kül; tullantı; kərpic; sinterləşdirmə; mexaniki xüsusiyyətlər.

ЛЕТУЧАЯ ЗОЛА КАК КОМПОНЕНТ СТРОИТЕЛЬНЫХ МАТЕРИАЛОВ

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Резюме: Проблема эффективного использования летучей золы является глобальной экологической проблемой, требующей срочного внимания и немедленных действий для её решения. Исследования показывают, что ежегодно образуются огромные объёмы летучей золы, однако лишь 25% этих отходов перерабатывается. Чтобы преодолеть эту тревожную ситуацию, необходимо сосредоточиться на увеличении использования его в различных отраслях промышленности. Перспективные направления применения летучей золы в строительстве, электронике, переработке ресурсов, очистке сточных вод, сельском хозяйстве и других отраслях требуют дальнейших исследований. Особый интерес представляет использование летучей золы в промышленных процессах. Физические, химические и минералогические свойства золы, такие как её морфология, удельная поверхность, пористость и химический состав, делают её идеальным материалом для различных технологических процессов. Расширение использования летучей золы в различных отраслях промышленности и её применение в процессах значительно повысит уровень её утилизации и снизит негативное воздействие на окружающую среду.
Ключевые слова: летучая зола; отходы; кирпич; спекание; механические свойства.