Application of ash and slag wastes in the production of building materials

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Abstract. One of the most important problems of humanity nowadays is environmental pollution, which affects human health and life. There are nearly 50 million tons of emissions (ash-slag wastes) realized in the environment per year, which indicates a physical contamination of nature and deterioration of the ecological situation on Earth. The processing and further use of emissions is a solution that can significantly reduce negative impact from industrial activity on the environment. The use of ash and slag emissions occupies one of the leading positions in this case. Recycled waste can considerably reduce the use of natural raw materials in construction industry. Ash-slag wastes, in contrast to natural ash, are not depleted, but on the contrary, their number increases every year, which in turn creates the prospects for their study and use. Replacement of material components with secondary waste will help to solve the problem of processing emissions, reduce the consumption of natural resources and contribute to introduction of new construction materials based on ash and slag waste. The appearance of such product can solve the problem of shortage of building materials in some regions of Russia (Altai and Primorsky territory). The paper is concerned with the results of complex processing of ash-slag wastes, description of products received by adding the components of such wastes, spheres of application, analysis of obtained characteristics, and comparison of the new product with the concrete without components based on waste.

1. Introduction
One of the global problems of mankind is the issue related to environmental pollution. Research in this area proves that if we do not eliminate or at least minimize the waste released to the environment, this will inevitably lead to an ecological catastrophe, which will have huge negative consequences for the entire planet. One of the main policies of developing in order to save the environment is resource saving. Resource-saving contributes to the saving of natural resources, to an increase in the output of products with a small amount of natural raw materials, materials and fuel.

The main areas in the resource-saving policy are: the integrated use of mineral resources and petroleum products; introduction of resource-saving equipment and technologies; restoration of land after the completion of industrial use. To date, the introduction of resource-saving technologies and recycling of secondary raw materials is a very significant problem, since the need for their implementation is an indispensable condition for the use of low-waste and non-waste technologies. Many regions of Russia (Amur Region, Khabarovsk Territory) do not have the opportunity to use natural raw materials because of their absence, in other regions (Murmansk Region, Arkhangelsk Region, Sverdlovsk Region), their reserves are considerably depleted. [1] In most cases, this leads to
significant costs for their transportation, since this is not advisable from both the economic and environmental point of view. With the development of the construction industry and the decline of ecology in the country, technogenic raw materials are becoming increasingly popular. The secondary raw materials include various industrial waste and by-products. [2] Most experts consider the technogenic raw materials as an indispensable product that collects all the resources previously spent on it. An important feature of construction and industrial building materials is the use of two types of raw materials - natural and technogenic (secondary). Introduction of technogenic raw materials from an ecological and economic point of view consists in: reduction of the consumption of scarce natural building materials, utilization of the amount of waste polluting the environment, reclamation of land previously allocated to ash dumps.

2. Ecological situation in the country
A large number of harmful emissions into the atmosphere are in the chemical, oil, mining and energy industries. In more detailed consideration of this issue, on the heaps of combined heat and power plants, 1.2 billion tons of ash and slag materials have been accumulated, which, in turn, occupy about 20,000 hectares of land (Figure 1). Ash dumps occupy a huge amount of arable land, which worsen the ecological state of the environment. The average annual production of ash and slag materials averages from 20 to 52 million tons, and the level of use of these wastes over the last decade is 5 to 15% of their annual production. These wastes are a serious source of environmental pollution and pose a great threat to human health, flora and fauna. The introduction of these wastes into the industrial industry, construction and agriculture is one of the most rational ways to solve this problem. At the same time, processing and use of ashes and slags as building materials can solve the problem of shortage of building materials in the regions. (Ulyanovsk Region, Orenburg Region, Penza Region, Irkutsk Region)[3].

2.1. Ash-slag waste as a component of the construction industry
Ash-slag waste is an integral component of molding mixtures for the production of high-quality building materials. They are used for the production of cellular concrete, fly ash, agloporite, non-gravel, road surfaces. Recycling and use of ash-and-slag wastes allows to save up to 35% of cement and more than 50% of natural aggregates. At present, ash-and-slag wastes are processed in very small amounts and are mainly used as additives in clinker and in cements [4]. To save cement, slags are crushed in grinding plants up to a dispersion of 240-310 m²/kg with subsequent introduction
into the concrete mix. The introduction of slag instead of part of the sand allows you to save part of the cement. When using finely dispersed slags, the dispersity of which is about 150-200 kg/m², exceeding the dispersity of clinker in cement, it is possible to save about 60% of cement in concrete composition while simultaneously increasing its strength by one or more grades.

Ash-slag waste can make a real revolution in the construction, as they have a number of unique properties, such as low thermal conductivity, high density. In order to save natural raw materials, reduce energy costs, labor resources, improve the state of the environment and solve a number of environmental problems, and to eliminate the deficit of necessary aggregates and improve the quality of concrete, it is necessary to use aggregates from waste. [5]

2.2. Examples of ash disposal

One of the vivid examples of processing of ash plant is agloporite - an artificial porous aggregate, which is obtained by sintering during the burning of granules of sandy-argillaceous rocks, as well as waste from extraction and processing of fuel. Agloporite can be used as a filler in lightweight concrete, for example, if you compare it with widely used expanded clay, agloporite is stronger and cheaper, among other things it can be made in the form of granules of the desired shapes and sizes. (Figure 2) At this point in the construction materials market, artificial porous aggregates that would have such high strength properties and low cost are simply not available. [6] The average capacity of agloporite is 82%, since the demand for a material such as agloporite is more than millions of cubic meters.

![Figure 2. Artificial porous fillers based on ash and slag materials (archive of ICTC)](image)

Also, ashes are used in the preparation of non-combustible ash gravel. From grains of non-burnt gravel, it is possible to produce concrete with a density of 800-2000 kg/m³ and with a strength of 6-50 MPa. The granules themselves have a density of 600-900 kg/m³ and a strength of 4.7-6.2 MPa. In order to make gravel easier, waste from porous materials and cellular concrete is used. One of the great advantages of this filler is that the fuel consumption for obtaining this material is much less than for firing aggregates. [7]

Another direction in the processing of man-made raw materials is a highly efficient waste-free technology for the production of bricks based on the ashes of thermal power plants. The brick can be produced both solid and hollow. In some cases, to improve the drying properties of the ceramic (clay-ash) mass, a small amount of fine-grained fuel slag (grain size less than 5 mm) is introduced into it. The distinctive features of the technology of ceramic products with ash from thermal power plants include: more uniform firing due to evenly distributed combustible fine residues in the ash burnt in the brick mass. [8] Higher quality products, including increased strength and lower density; lower consumption of process fuel. From a technical and economic point of view, the addition of ash leads to a reduction in the cost of producing products, reducing the cost of raw materials, reducing the
cost of finished products. If compared to silicate bricks, the ash bricks have low thermal conductivity, low density and weight (table 1).

Table 1. Comparative characteristics of ash and silicate bricks with voids

| Characteristics              | Brick ash with emptiness, 25% | Silicate brick with voids, 25% |
|------------------------------|-------------------------------|--------------------------------|
| Average density              | 1100                          | 1600                           |
| kg / m³                       |                               |                                |
| The weight                   | 1025                          | 1640                           |
| 1 m³ (kg)                    |                               |                                |
| Thermal conductivity         | 0.15                          | 0.6                            |
| W / m°C                      |                               |                                |
| Wall thickness (cond.)        | 0.25                          | 1                              |
| Compressive strength         | 125-200                       | 125-200                        |
| MPa                          |                               |                                |

According to the calculations of research organizations, the production of concrete solutions on average per year can consume about 33 million tons of ash and ash and slag. [9] Replacement in concrete of a part of cement to ash, in recalculation to the global volumes of their application, can significantly reduce the amount of carbon dioxide (CO₂) emissions into the atmosphere by 270-300 megawatts per year. At this time, less than 0.6 million tons of ash per year is used in the production of lightweight concrete [10].

The main material of the construction industry has always been reinforced concrete, which in recent years has a tendency to change its performance, namely, reduction in mass and thermal conductivity. There is a replacement of heavy concretes for lighter ones, which include artificial aggregates [11]. Constructed lightweight concrete, compared to heavy, is easier by 25-55%, despite the same production technology, lightweight concrete can reduce the heat transfer of the building, increase the level of thermal protection and vapor permeability. Such concrete, among other things, is widely used in road construction [12]. Roads with the use of such material do not freeze and serve several times longer. Cellular gold-cement concretes are widely used. Their characteristics are significantly different from conventional cellular concrete, which allows them to be introduced as another new building material that is not inferior to its analog (table 2) [13].
Table 2. Comparative characteristics of gold-cement and cement-sand aerated concrete (non-autoclaved hardening)

| Characteristics                        | Zolo-cement aerated concrete (non-autoclave) | Cement-sandy aerated concrete (non-autoclave) |
|----------------------------------------|---------------------------------------------|----------------------------------------------|
| Compressive strength MPa in (age 28 days) | 2.1                                         | 1.6                                          |
| Mix                                    | Higher than for cement-sandy by 30-60%      | -                                            |
| Thermal conductivity W / m°C            | 0.17                                        | 0.21                                         |

3. Problems of involving secondary raw materials in turnover

Despite the large amount of industrial waste, and the proven high demand for their use in the production of building materials, Russia, in this matter, lags behind the world level. One of the main reasons preventing the involvement of waste in the production of large building materials is: the lack of legal mechanisms to attract ash and slag materials to the commodity turnover; lack of effective state policy in the field of resource saving; lack of resources and mechanisms for mass production, storage, transportation and processing of waste in finished products; not orientation to secondary secondary raw materials, since the whole system is aimed at the use of fresh natural resources; expulsion from the market of old building materials, competitive struggle.

4. Conclusions

Another reason for the low level of use of technogenic raw materials, in addition to the above, are different approaches to this problem in economically developed countries and Russia. Technogenic raw materials, acts as a commodity, and not as recycled raw materials, which is of little interest for most building materials, in view of the use of primary natural resources. In modern limited conditions, one of the main factors is the development and implementation of new technologies, which are the basis of resource saving, which include: increasing the efficiency of using material, natural, labor and financial resources. This reduces production costs, which leads to a reduction in the cost of production. Summarizing, we can say that the use of waste for construction could significantly reduce the cost of concrete products by several times, increase the number of building materials, which would allow solving the big problem of building new cheap housing in a short time. And to solve one of the important problems of environmental pollution with waste and emissions from various industries.

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