# USE OF INDUSTRIAL WASTE IN THE CONSTRUCTION INDUSTRY

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According to the latest data from environmentalists, Ukraine leads Europe in terms of waste accumulation. Indicators of waste generation and accumulation in Ukraine testify to the threatening environmental situation in the state. According to the Ministry of Ecology and Natural Resources of Ukraine, about 35-36 billion tons of waste have been accumulated in our country, which occupy approximately 7% of the territory. Of these 35-36 billion tons, about 2.6 billion tons are highly toxic waste. It should be noted that each Ukrainian now accounts for more than 750 tons of waste. Every year in Ukraine, from 670 to 770 million tons are generated, while only 30% of industrial and 4% of household waste are utilized [1-5].

Industrial waste and household waste are one of the most significant factors of environmental pollution and the negative impact on virtually all of its components. Infiltration of household and man-caused industrial waste disposal sites, burning waste heaps, dust formation, and other factors that cause the migration of toxic substances lead to pollution of ground and surface waters, deterioration of atmospheric air, land resources, etc. [6-9].

Future prospects for the development of enterprises in the building materials industry are at the stage of a radical reassessment due to the acute shortage of energy resources. To solve the problems of reducing the cost of the final product of construction and reducing the cost of raw materials, fuel and energy and other resources, a special role is given to expanding the use of both industrial and household waste [10-12].

The problems of formation and rational use of waste, as a component of resource saving and greening of production, are devoted to many scientific works. However, the lack of research on this issue causes a number of problems in the use of industrial and municipal solid waste and necessitates further research in this direction.

The "Laboratory of resource-saving technologies and special concretes" of Vinnitsa National Technical University (VNTU) conducts research on the integrated processing of phosphogypsum waste, fly ash, red bauxite and metal helmets, as well as municipal solid waste. The purpose of these studies is to develop a new waste-free technology for processing industrial waste with the subsequent production of an effective low-clinker binder and special-purpose building materials.

The task of increasing the strength of building products can be solved by effective traditional technological methods - through the use of complex chemical and active mineral additives. But if the use of active natural mineral additives in the composition of raw mixtures requires additional costs for their production, then 12 thermal power plants operated in Ukraine annually send 10 million tons of fly ash to dumps. The proportion of the use of such raw materials of technogenic origin by domestic enterprises of building materials is 5-8 times less than in foreign countries [13-14].

Fly ash is a finely dispersed material, consisting, as a rule, of particles ranging in size from a fraction of a micron to 0.14 mm. 100 μm [15].

In works [15-16], the authors found that the main components of ash - $SiO_2$, $Al_2O_3$ are predominantly in the form of vitreous phases. As a result of the research, it was found that the activity of ash increases with an increase in the content of vitreous phases.

One of the promising research areas of VNTU is the activation of ash and slag waste for their further use in the production of building materials. In our opinion, the chemical activation of fly ash with acidic phosphogypsum residues or alkaline red mud is the least energy-intensive, efficient and environmentally friendly technology for industrial waste processing.

A complex method of mechano-chemical activation of fly ash involves the destruction of the surface of the vitreous shell of particles by using acid residues from phosphogypsum or its dissolution in the alkaline environment of red mud with simultaneous mixing of the mixture. The use of mechanical mixing of ash-slime and ash-phosphogypsum mixtures contributes to a more complete activation of the charge [17-18].

Phosphogypsum waste is a by-product in the production of phosphoric acid by the extraction method. The chemical composition of phosphogypsum of Vinnitsa PO "Khimprom" is as follows: CaO 7.42–12.8%; $SO_3$ 2.41–6.25%; F 3.55–5.81%; $P_2O_5$ 14.49-21.18%; RH 13.21–15.78%; $H_2O$ 9.76–16.07%, hydrochloric acid residue 6.66–17.7% [19].

Differential thermal analyzes (DTA) of cement stone with different amounts of ash, conventional and treated with acid effluents of phosphogypsum, as well as a control sample without the addition of fly ash, show that the following thermal effects are recorded on the DTA curves: a bifurcated endothermic effect in the temperature range of 100 - 120 °C with maxima at 105 - 150 and 180 °C, indicating the removal of adsorption water from hydrate neoplasms. A sharp endoeffect with a maximum at 500 - 520 °C is associated with the dehydration of calcium hydroxide - $Ca(OH)_2$. A diffuse exothermic effect at 880 - 905°C indicates the presence of low-basic calcium hydrosilicates, most likely a hydrosilicate gel. In samples with activated ash, a deeper endoeffect can be seen on the DTA curve than in a sample with non-activated ash, confirming the presence of a significantly greater number of hydrate neoplasms.

Studies of cement and ash-cement samples (Fig. 1) indicate the presence in their composition of non-hydrated clinker minerals C3S - lines with interplanar distances d / n = 3.02; 2.77; 2.75 2.18; 1.76; 1.45 A; C2S - lines with d / n = 2.77; 2.18; 1.97 1.76; 1.45 A; Ca $(OH)_2$ - lines with d / n = 4.90; 3.10; 2.62 1.92 A; $CaCO_3$ - lines with d / n = 1.82 A; quartz - lines d / n = 3.34 A. In addition, there are lines characteristic of hydrate neoplasms - low-basic calcium hydrosilicates (CH) - d / n = 3.08 A.

In ash-cement samples with the addition of activated ash (sample 3), complex aluminum-iron-hydrosulfonic calcium compounds appear, which are characterized by lines with d / n = 2.45; 3.07; 4.22; 7.62 A. The presence of such neoplasms in the composition of ash-cement samples can be explained by the fact that aluminum and iron sulfates are formed during the chemical activation of fly ash. X-ray diffraction patterns and DTA confirm the presence of such salts and the possibility of their participation in the processes of binder hardening.

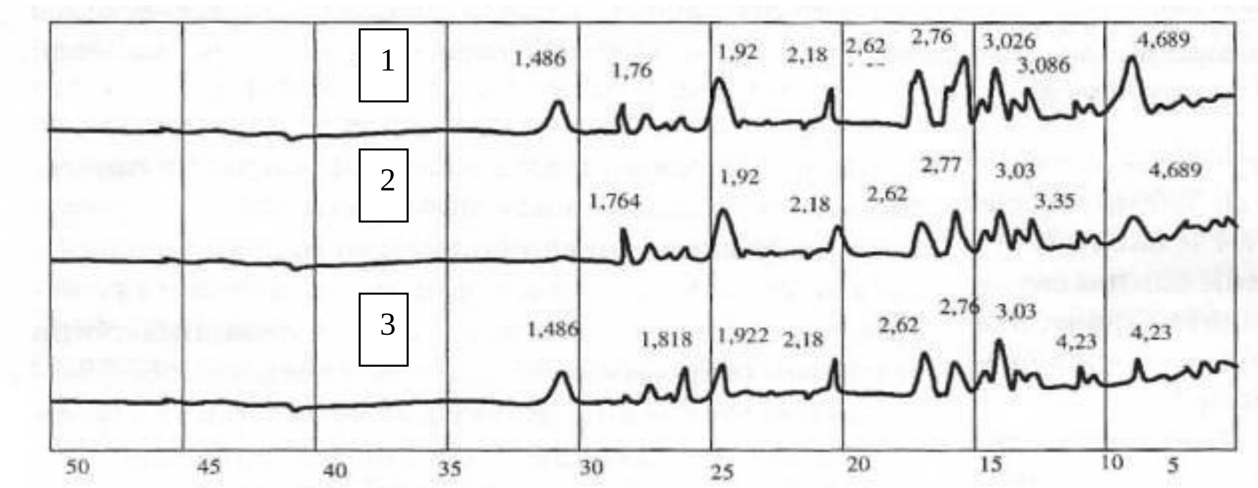


Fig. 1. Radiographs of prototypes: 1 - cement sample; 2 - cement sample with the addition of 30% non-activated ash; 3 - cement sample with the addition of 30% chemically activated ash.

Red bauxite mud has a fairly high alkaline environment. Therefore, the use of red mud for the chemical activation of fly ash also leads to the destruction of the glassy surface of the ash waste, which makes it possible to save a highly energy-intensive component of the building mixture - cement. The authors in [20-21] proved that the addition of bauxite sludge to the composition of the ash-cement mixture ensures the intensification of the processes of neoformations of the mineral-phase composition and ensures the economy of the mineral binder.

In modern materials science, the direction of creating clinker-free metal phosphate systems as an alternative to composite heat-resistant building materials is relatively new. Among the varieties of such materials, ferrophosphate cements were obtained, capable of withstanding high temperature loads, which was proved by scientists in the conducted studies [22-23]. Metal phosphate cement is widely used in the production of heat-resistant concrete. Iron-containing industrial waste is used as an oxidized component of such a binder [24]. In their research, the authors used pyrite cinders, consisting of 70-75% $Fe_2O_3$, 5-6% FeO, about 14% quartz and 1-1.5% sulfates. Research has established that it is possible to change the physical and mechanical properties of the material by varying the acid concentration in the metal phosphate binder [25-26].

The use of a clinker-free binder based on metal phosphates and the addition of fly ash made it possible to create a new building material with a complex of multifunctional properties. The resulting composite material can be compared with structural building materials in terms of its physical and mechanical characteristics. The studies of the samples in works [27-28] showed that with a content of metal filler in the range of 30-70% by mass. as part of the mixture, their compressive strength was 6.5 - 8.4 MPa with an average density of 1780–2160 kg/m3.

The preliminary analysis showed that samples of metal-saturated composite material have good electrophysical properties along with high physical and mechanical characteristics. The results of the research of a number of scientists show that when the content of the mixture of metal filler changes in the range of 10-60% by mass. the value of the specific resistance of the material varies from $10.4\ 10^{-3}\ \Omega \bullet m$ to $2.3\ \Omega \bullet m$ [29-30].

In [20], it was shown that the main direction of red mud utilization in the production of building materials is its use as a modifying additive to the ash-cement binder, the introduction of bauxite sludge significantly affects the change in the new formations of the ash-cement stone.

It should be taken into account that industrial waste can be widely used to obtain special building materials [31]. Special materials developed at VNTU include composite concrete with protective properties against electromagnetic radiation [32], static electricity [33], anode ground electrodes for protecting underground engineering structures [34].

It was confirmed in [35-36] that the use of Betel-m with a cellular, variotropic and dense structure makes it possible to reduce the level of electromagnetic radiation, and cellular electrically conductive composite metal-saturated concrete is an effective radio-absorbing material. As an electrically conductive component, it is advisable to use metal sludge from ball bearing production. Such sludge is not subject to further processing, since on its surface it contains a large amount of coolant, which consists of an oil emulsion [37].

In the article [38], it was found that by changing the type of electric current, its magnitude and duration of flow, it is possible to control the physicochemical processes during the hardening of composite metal-conducting concrete, and, consequently, the electric characteristics of Betel in the right direction.

In [38-39], the expediency of using finely dispersed powders of SHX-15 steel sludge for the manufacture of a special protective coating is substantiated. In [40-41], it was proposed to use a coating from electrically conductive concrete to combat static electricity charges, the manufacturing technology of which is quite simple and does not require expensive materials and special equipment. It has been established that in order to obtain an antistatic coating that meets the requirements of electrical conductivity, physical, mechanical and aesthetic requirements, it is necessary to produce coatings on a large dielectric filler.

The authors in [42-43] confirm that Betel-m can be used for the manufacture of electrically conductive elements (anodic ground electrodes) of anti-corrosion cathodic protection systems for underground engineering networks, and the formation of such products must be carried out using simultaneous exposure to the prepared mixture of electromagnetic and mechanical methods. The formation of products in this way provides an improvement in the physical, mechanical and electrophysical properties of the elements of anode ground electrodes.

As a result of the research, it was established:

- the production of building materials is one of the most material-intensive industries, the use of industrial waste as a raw material in the manufacture of building materials can be used to significantly reduce the rate of depletion of natural resources;

- industrial waste can be successfully used to create a clinker-free binder and special-purpose materials.

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