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Article

Use of recycled waste in the production of building materials

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Abstract. With the development of modern society, technological progress does not stand still. Mankind is constantly in search of new ideas and ways of implementation. This article of the authors is part of the modernization of the existing system of production of building materials. The authors propose to use secondary raw materials for the manufacture of a standard product, confirm them with laboratory tests and results. The indicators of the modified concrete mixture with the addition of ash-and-slag waste from the local industrial sector gave a density not inferior to the heavy concrete of 1.8 g/cm^3. Positive effect is obtained by using hydraulic press, where at equal ratio of components due to pressing, all samples were transferred to a number of heavy concretes with a density of 1.8 to 2.5 g/cm^3. Moreover, it was found that there are reserves of cement saving in the application of ash in the case of samples prepared by means of hydraulic press, as well as to correct the composition of concrete it is required to carry out a full-scale experiment with the joint action of vibration and pressing. Strength tests of samples show that there is an optimum quantity of ash and slag in the formulation, at that not only the standard requirements for the quality of construction products are met, but also exceeds some characteristics of products according to the requirements of standards.
Keywords: recycling, secondary raw materials, ash and slag waste, building materials, waste-free production, new materials.

1. Introduction

The development of modern society has formed a new kind of consumer, which has led to an increase in the rate of production in all sectors of the economy. This pattern can be seen in the intensity and acceleration of scientific and technological progress, which leads to the depletion of resources and minerals, as well as the negative impact on the environment. Despite this, the use of industrial waste is often criticized as well as supported. Non-waste technology is divided into two types. The first type is defined as the original material or semi-finished product for finished building materials or products. The second type is called secondary raw materials, which appeared as a consequence of the production of one product and can serve as initial raw materials for the second one. Common materials for recycling are: car tires, paper flour, construction debris, polymeric materials, which allows you to get crumb rubber, paper, crushed stone from recycled concrete, insulation materials and more [1].

The problematic topic of the use of industrial waste is the assessment of its market value. In this regard, the process of using secondary raw materials is divided into two stages. The first stage is the purchase of raw materials for processing, and the second stage is the production of secondary raw materials. An important role in all this is played by the quality of the primary recycled material, which should correspond to [2], where the norms of hard-to-recover losses and waste materials, which are reflected in the final cost of secondary raw materials. It is worth noting that recycling generates another volume, which is no longer suitable for use and requires more serious measures to eliminate. Thus, we can conclude that the lack of a clear systematic approach to assessing the value of secondary raw materials and the industry as a whole cause a number of issues that require specific measures to eliminate them, as modern construction places high demands on the quality of the material while maintaining a low cost of production [3].

Among the CIS industrial giants, the Russian Federation alone has seen an increase in slag deposits of one million tons per year. These enterprises include thermal power plants, thermal power plants, coal enrichment, ferrous and nonferrous metallurgy. What not to say about the experience of foreign countries [4]. The way of using man-made materials as mineral raw materials is practiced in Poland, where metallurgical slags are exported to neighboring countries for the production of road pavement and construction materials [5]. In England ashes are used to partially replace cement and sand. In the USA ashes from thermal power plants are introduced into the concrete mixture in a certain ratio to cement to increase the density and sulfate value of concrete [6]. The experience of foreign countries in the use of ash is well described in [7], which concludes with a review of the current European standards [8-9], because the level of combustion products in the European Union countries is quite high (Figure 1).

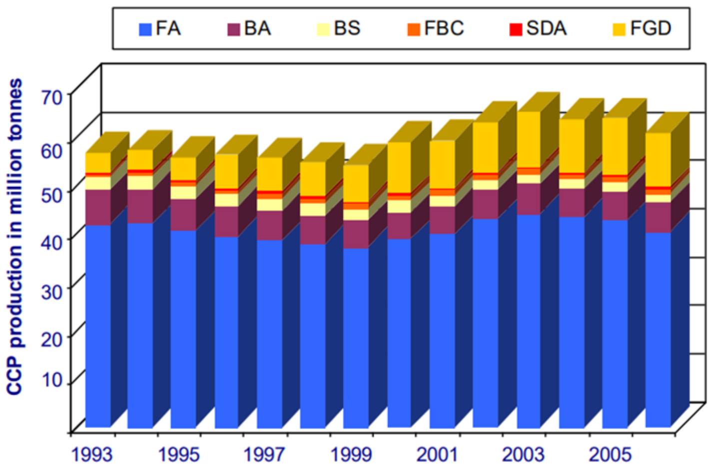

Figure 1 – Volumes of ash production in the EU [7]

The same analogy can be made based on the characteristics of the landfills of some rock dumps located in the Central Kazakhstan region. In essence, the ash contains 53 % of SiO_2, 24 % of Al_2O_3, 10 % of Fe_2O_3 and FeO, 2 % of CaO, 1 % of MgO, 4 % of oxides of alkali metals and 6 % of unburned fuel, which is often found in the composition of waste in rock dumps (Table 1).

Table 1 – Landfills of rock dumps of the Central Kazakhstan region

No.	Polygons	Area, ha	Hazard class	Amount of waste, tons/year	Total amount, tons	Waste composition, %
1	BGMK rock dumps, Kazakhmys Corporation, Sayak settlement	319	5	2397600	307305600	SiO_2 – 74 $CaCO_3$ – 21.5 $MnCO_3$ – 3.8 Fe2O3 – 0.3
2	BGMK rock dumps, Kazakhmys Corporation, Konyrat settlement	941	5	-	743898500	SiO_2 – 54.4 Al_2O_3 – 24.8 Fe_2O_3 – 7.4 As – 0.002 Pb – 0.001
3	Vostochnaya Central Processing Plant rock dump, JSC IspatCarmet, Pridolinskiy settlement	70	5	99300	14432800	Zn – 0.004 Cu – 0.005 Gr – 0.0045 P – 0.06
4	Rock dump of ChOF, JSC IspatCarmet, Temirtau	159.9	5	844600	41356800	SiO_2 – 60.2 Fe_2O_3 – 5.73 Al_2O_3 – 24.3

						Cu – 1.57 MnO – 1.45
5	Rock dump Sh. Kazakhstanskaya, JSC IspatCarmet, Shakhtinsk	153	5	78600	35190000	As – 0.0002 Pb – 0.003 Zn – 0.01 V – 0.015 Mn – 0.15

Based on foreign experience, "Construction" is the only industry that is able to use the full potential of waste and by-products of other industries, which is the use of waste energy sector - ash and slag of Pavlodar CHPP-1, since the properties of ash is a fine material, which can be used as an additive to cement, aerated concrete, lime brick, and the chemical composition as mentioned above is identical to natural raw materials and can serve as a full and inexpensive alumina [10].

The involvement of any industrial sector allows to reduce the huge amount of space used for landfills and storage sites, which has a positive effect on the environment and the biosphere as a whole.

Thus, the Republic of Kazakhstan approved a program for the development of the construction industry and production of building materials for 2010-2014 [11], which states the favorable dynamics of development of the building materials industry, touched upon the issues of cost price and quality of materials. In this connection, a priority task was formed on the need for accelerated development of the basic sub-industries of cement, precast concrete, thermal insulation materials, glass, building ceramics, etc. with the maximum use of positive foreign experience and modern technology. The significance of the ongoing research is reflected in the second block: Energy saving in the production of powder, lumpy materials through the use of dispersed man-made products (ash, slag, slime, tailings, etc.), which substantiates the work of the authors of this article.

2. Methods

For the experiment, a formulation of mixtures for the industrial production of 3 types of building materials was developed: Paving slabs; Curbstone; Hollow stone.

The composition of the selected mixtures includes directly ash and slag waste (ASW) from thermal power plants and bauxite sludge from alumina production. Laboratory studies on the selection of the formulation are based on steelmaking slag from local steel mills and were carried out at the Independent Testing Center of Novosibirsk State Technical University.

The following materials were used as raw materials for the production of the studied samples of concrete:

- Sand [12];
- Portland cement PC-400-D20 [13];
- Fly ash from Pavlodar CHPP-1 (Table 2);
- Water [14].

Table 2 – Chemical composition of fly ash from Pavlodar CHPP-1

Components	Al_2O_3	SiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	SO_3
Contents, %	28.6	60.6	5.4	2	0.5	0.5	0.2	0.7	0.1	0.62

For the production of a basic sample of concrete Z0040, sand, Portland cement and water were used as materials. The base sample in terms of dry component included: 40% cement and 60% sand. The water-cement ratio was taken to be 0.35.

For the other series, each of which consisted of 6 samples, fly ash was introduced by replacing sand and Portland cement in 10 % increments, with 5 % of the sand and 5 % of the Portland cement being replaced. Dry components were mixed together, then water was added. The composition of the resulting concrete mixtures is shown in the graph (Figure 2).

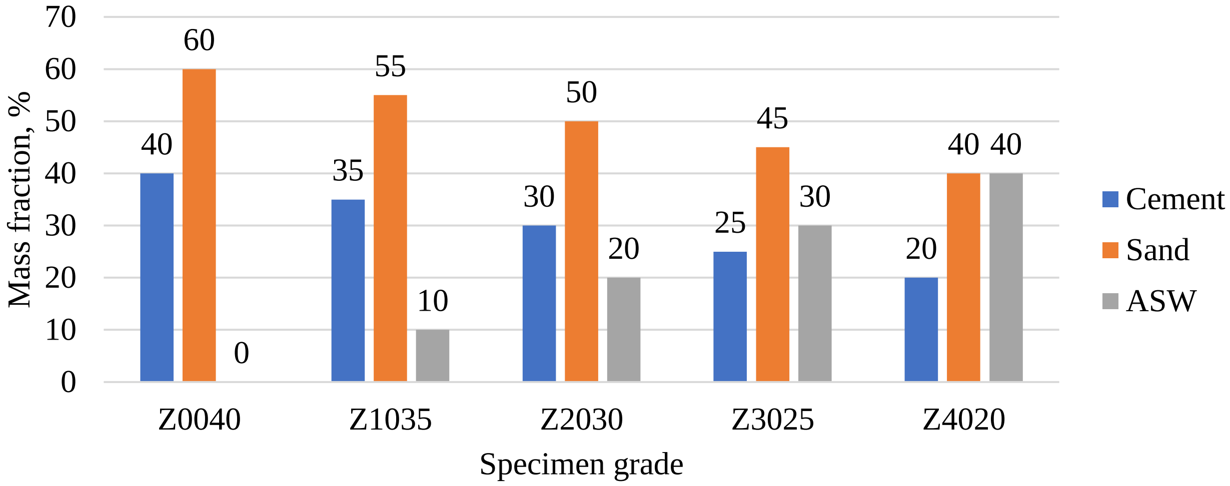

Figure 2 – Compositions of concrete mixtures using ASW

The vibropress designed for pressure of 100 kg/cm2 (10 MPa) and vibration frequency of 50 s^{-1} with an amplitude of 0.35-0.5 mm was used for the experiment.

The first stage of the experiment uses a vibration table (VT) with a vibration frequency of 3000 rpm at an amplitude of 0.4 mm. For the experiments, cube shapes 100x100x100 mm with the bottom were used (Figure 3). Determination of the density of concrete samples was carried out in accordance with [15].

Figure 3 – Samples of cubes after the vibrating table

At the second stage of the experiment a hydraulic press (HP) PGM -100MG4 was used, but in this case, cube shapes 100x100x100 mm without the bottom were used, the composition of the concrete mixture was identical to the first (Figure 4).

Figure 4 – Samples of cubes after the hydraulic press

Next, a P-10 press was used to determine the strength characteristics of concrete cube samples at 28 days of age (Figure 5).

Figure 5 – Hydraulic press testing process

3. Results and Discussion

The graph below shows that the density of concrete decreases as the percentage of the mass component of ash in the concrete mixture increases. Samples Z0040 and Z1035 have a density above 1.8 g/cm^3, so they belong to the class of heavy concrete. Samples of grades Z2030, Z3025, Z4020 can be attributed to the class of lightweight concrete (Figure 6).

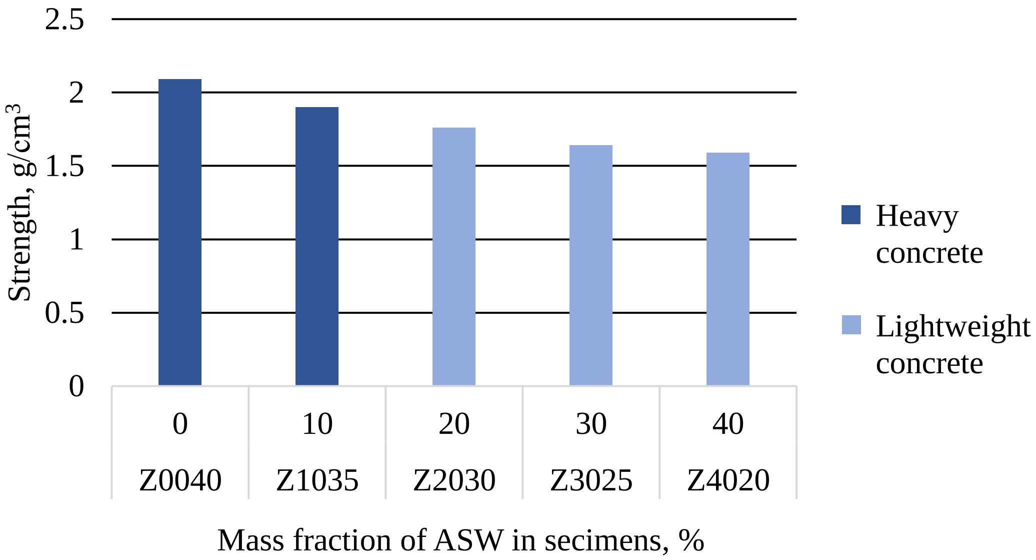

Figure 6 – Density of concrete samples obtained after using the vibrating table

After using the hydraulic press PGM, noticeably, the density of concrete samples became higher than at the first stage of the experiment, on average 1.2 times. Now all samples belong to the heavy class of concrete (Figure 7).

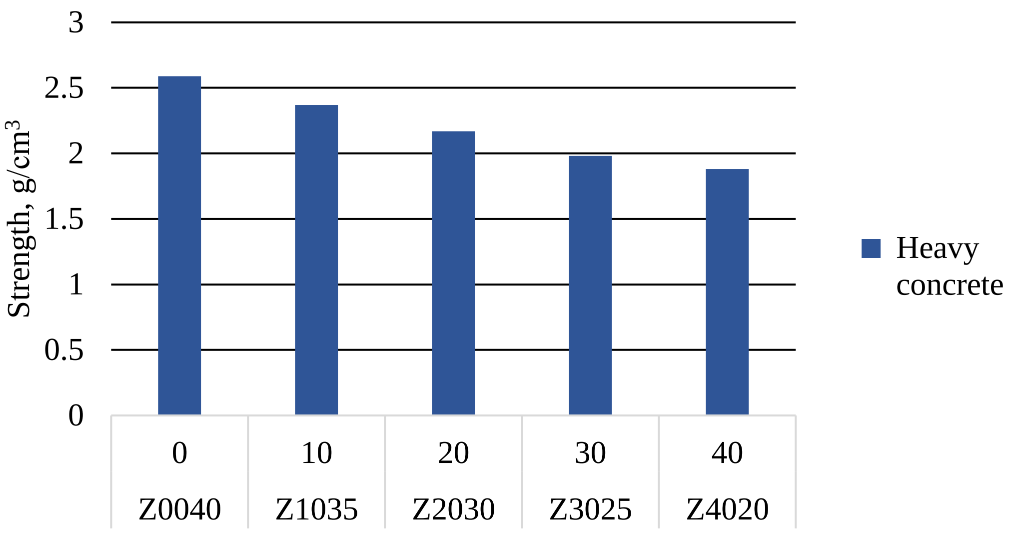

Figure 7 – Density of concrete samples prepared on a hydraulic press

The use of ash is based on a number of its physical and chemical properties, namely on its pozzolanic activity. This refers to the ability of ash to interact with calcium hydroxide and alkalis in the pore fluid of concrete [16]. There is an opinion that ash is an ideal binder for reinforced concrete products and factory-type structures [17].

According to the results of experiments, it can be argued about the sufficient strength gain of compositions for the manufacture of products with the addition of ash-and-slag mixtures to the concrete mixture.

4. Conclusions

On the basis of tests of samples using ash and slag from Pavlodar CHPP-1 it was found that:

- There are reserves of cement savings in the application of ash in the case of preparing samples using a hydraulic press.

- To adjust the composition of concrete it is required to conduct a full-scale experiment with the joint action of vibration and pressing.

Strength tests of samples show that there is an optimum quantity of ash and slag in the formulation, at those not only standard requirements to the quality of building products are met, but also exceeds some characteristics of products according to the requirements of standards.

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