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Utilization of Coal Ash for the Production of Building Materials as an Effective Solution to the Environmental Problem

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Abstract: *The article discusses the technology of production of building materials using the ashes of thermal power plants. The methods of utilization of Angren brown coal ash as a filler of multicomponent cement materials, as well as the operating modes of the technology of production of products from ash-cement mixtures are shown. The results obtained show the high economic and environmental efficiency of the proposed technology in the production of building composite materials.*

Key words: *Ash, brown coal, ash utilization, structure formation, integral indicators, environmental problem, building compositions, water demand, strength, mobility, normal density.*

1. Introduction

Utilization of coal ash in its current form began with the use of pulverized coal fuel combustion technology in the production of electricity in the 20s of the last century, when coal ash became available in large volumes. In the foreseeable future, coal remains the only and most significant type of fuel in terms of reserves [1].

All over the world, 38% of electricity is currently produced from coal, mainly at power station using pulverized coal fuel [2], the reserves of which will last more than 200 years.

Explored coal reserves in Uzbekistan amount to 1900 million tons, including brown coal - 1853, hard coal - 47, forecast resources are 5760, of which brown coal - 5188.2; stone - 571 million tons [3].

As can be seen from the above, more than 70% of the mined coal is brown coal from the Angren deposit, which is low-calorie and high-ash. The main studies were carried out on the ashes of the Fergana and Pap Thermal Power Plants, as well as on the ashes of the Angren Thermal Power Plants, where brown coal of the Angren deposit is used.

At present, more than 50 million tons of coal ash have accumulated at New-Angren and Old-Aren Thermal Power Plants after burning Angren brown coal when generating electricity, the volume of which increases annually by 1.5 million tons, which occupies vast territories, with wind rises into the atmosphere and creates an ecologically dangerous situation in the environment [4].

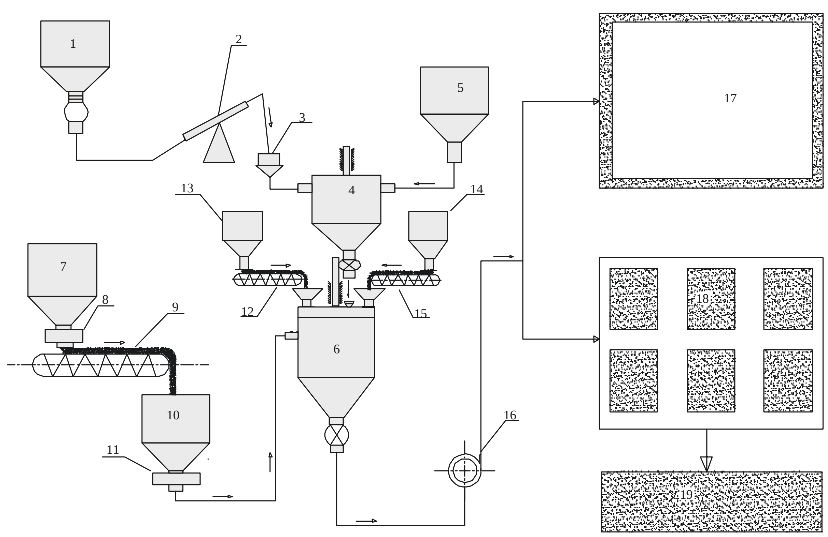
It should be noted that there are many areas where ash from thermal power plants is used, where it can be used as a heat-insulating material, mineral fertilizers, in road construction as asphalt bases and others. There are many ways to obtain the beneficial properties of ash, for example, obtaining a dry building mixture by mechanical crushing, extracting useful elements by chemical means, which makes it possible to obtain high-quality complex mineral fertilizers, and by sieve separation, to obtain as a basis for road construction in the territories of thermal power plants, which contributes to improving the environmental situation in the areas of located Thermal Power Plants.

In particular, in accordance with modern ideas about the structure of multicomponent materials, the introduction of ash into the composition of cement systems is a binder filling, since ash is a typical highly dispersed filler. This approach to cement-ash systems is very important, because it makes it possible to use methods for calculating the optimal filling, binder and to obtain extrema of strength indicators from the standpoint of the polystructural theory of composite building materials [5].

2. Method

The technology developed for production conditions consists of the following stages (pic. 1). Tap water through the measuring tank 1 enters the solar collector 2, where it is heated to 38-410C, after which it enters the sprinkler for heat exchangers 3, where its temperature is brought to the optimum.

Technological scheme for the production of ash-cement materials



Pic. 1 1 - measurer; 2 - solar collector; 3 – sprinkler for heat exchange; 4 – dispenser for modified plasticizing additive; 5 - container for liquid target additives; 6 – turbulent grout mixer; 7 - container for ash; 8 - dispenser; 9 - auger; 10 - sieve; 11 - ash dispenser; 12 - screw for cement; 13 - container for cement; 14 - container for dispersed targeted additives; 15 - screw for lime; 16 - mortar pump; 17 - solid formwork for walls; 18 - forms for finished products; 19 - combined solar plant

Then it is sent to the dispenser 4, which also receives a modified plasticizing additive from the tank of liquid target additives 5. After mixing, the mixture (aqueous solution) enters the mortar mixer 6. The ash from the tank 7, having passed the dispenser 8, is fed into the sieve using the screw 9 10 to remove coarse slag. Then the ash in a certain dose is fed to the dispenser 11 and sent to the mortar mixer 6, into which cement is also fed from the tank 13 and lime from the tank for dispersed target additives 14 by the screw 15. After obtaining a homogeneous mass, the prepared solution is pumped by the pump 16 to the molds for molding products 17, 18. The resulting products are sent to the combined solar plant 19, where, in the process of heat treatment, the products reach the required strength [6].

The most important characteristics of ash-cement materials, which determine their durability, are water absorption and frost resistance. Analysis of samples after heliothermal chemical exposure shows that with increasing density, their weight and volume water absorption decreases, the softening coefficient of ash-cement materials is insignificant (3-4%). A sharp decrease in water absorption is observed in the case of mechanochemical activation of the system under optimal temperature conditions, which indicates a significant decrease in the capillary and open porosity of the structure.

Hydrophysical parameters of ash-cement materials are closely related to frost resistance [7,8,9]. It has been established that in all the used compositions of samples with additives of modified plasticizing additive and lime, a sufficiently high frost resistance is observed that meets the requirements of building codes. For ash-cement materials, a directly proportional dependence of the frost resistance coefficient and deformation kinetics under a short-term load on the sles on the cement consumption was noted.

3. Results and discussion

Research has found an analytical dependence that takes into account the following factors: temperature rise at the calculated point due to internal heat release, taking into account the absorption beam coefficient

$$\Delta t_{q_i}^{j-1} = \frac{m_v \cdot \Delta\tau}{c \cdot \rho} \cdot q_{E \cdot i}^{i^*} + q_l^i \cdot k_i,$$

where c is the specific heat capacity (830-870 W/mK), mV is the mass of cement in 1 m3 of concrete (180-295 kg/m3), ρ is the product density (1316-1530 kg/m3), q_E^o is the intensity of heat release from cement hydration (W/m3), q_l^i - specific heat due to the absorption of solar radiation, (W/m3), - k_l^i - coefficient of radiation absorption at 80% ash filling (0.81 W/m^{2}K).

The amount of heat released into the volume of the product over time Δτ

$$Q_E^{ij} = m_v \cdot \Delta\tau \int_V q_E^j \cdot dv + \frac{1}{k_i} \int_V q_E^i \cdot dv \approx m_v \cdot \Delta\tau \cdot \Delta x \sum_{j=1}^{K} Q_l^j + \frac{1}{k_i} \sum_{i=1}^{S} Q_l^i;$$

where j, i is the index of the moment of time, determined by the method of equal heat release and the time of radiation absorption.

Specific intensity of the heat flow qe generated in a combined solar power plant

$$q_F = -\frac{\lambda}{\Delta x}(t_r^{j-1} - t_1^{j-1}) + \Delta x \cdot \lambda \cdot c \cdot \rho (t_r^j - t^{j-1}) \cdot 0{,}5 - \lambda \cdot m_v \cdot \Delta x \cdot q_E \cdot 0{,}5 + \Delta x^2 + q\Delta x K_i$$

The amount of heat required to heat the product due to solar thermal treatment

$$Q_F^{ji} = q_{\mathrm{E}}^j \cdot \Delta\tau + q_{\mathrm{l}}^i \cdot \Delta\tau + q_l^i \cdot \Delta r^1;$$

Efficiency ratio

$$K = \frac{Q_E}{Q_r} \cdot 100\%.$$

The calculation algorithm is implemented in TURBO PASKAL 6.0 for Pentium-4. The counting time for each option is 15-17 minutes. The results of the problem posed for were analyzed in three sections, which corresponded to the points N2, N3, and N4.

Boundary parameters of heliothermal-chemically treated ash-cement fine-grained product on interlayers were established (Table 1).

Table 1. Boundary parameters of heliothermal chemically processed ash-cement fine-grained product on interlayers

Boundary points	l_1=0.1±0.001m			l_2= 0.2±0.001m			l_3= 0.4±0.001m		
	Δt^1, °C	t^1, °C	Q_E^1, *MJ*	Δt^2, °C	t^2, °C	Q_E^2, *MJ*	Δt^3, °C	t^3, °C	Q_E^3, *MJ*
N2	16.2	79.10	1.44	18.9	77.91	3.32	18.97	71.32	4.92
N3	14.6	80.45	1.31	18.1	76.21	3.11	14.17	60.62	3.41
N4	13.9	80.67	1.31	17.2	73.20	2.93	9.07	51.07	2.32

It is noted that the data obtained correlate well with the kinetics of heat release in ash-cement systems (Table 2).

Filling with ash by 20, 40, 60 and 80% reduces heat generation by 17, 40, 50 and 57%, respectively. The introduction of modified plasticizing additive reduces heat release by 5; 6, 4; 8% in the following order modified plasticizing additive -1 > modified plasticizing additive -3 > modified plasticizing additive -2. This is due to the selective adsorption capacity of modified plasticizing additives on the active centers of the surface of ash and cement particles.

As the thickness increases, the heating of the inner layers of the product, as studies show, lags significantly behind the heating of the outer layers. Consequently, the magnitudes of the maximum and the time of their appearance at the studied points of the product differ significantly from each other, which indicates the integral indicators of a fine-grained multicomponent product during heliothermal chemical treatment (Table 3).

Table 2. Time indicators of heat release of ash-cement materials during heliothermal chemical treatment

Terms for determining heat release, hour	Temperature rise (°C) at ash content, Wt. %				
	0	20	40	60	80
5	18	9	7	5	4
10	38	28	21	12	8
15	29	25	23	29	16
20	17	18	16	19	16
25	13	12	10	9	8
30	8	7	6	6	6
35	6	5	5	4	4

Table 3. Integral indicators of heliothermochemically processed ash-cement fine-grained product

l, m	q_E, кWt /m^3	τ, max, *hour*	Q_E, *MJ/m^3*	Q^*, *MJ/m^3*
0.1 ± 0.001	4.86	5	4.31	42.10
0.2 ± 0.001	4.11	6	8.20	39.81
0.3 ± 0.001	2.07	8	15.31	38.21

l, m	t, ^oC	Δt, ^oC	Q_f^*, *MJ/m^3*	τ, *hour*	$Q^*_э / Q_f^*$, %	$Q^*_э / Q^*_{req}$, %
0.1±0.001	80.45	14.42	13.21	5	31.87	16.84
0.2±0.001	77.92	16.94	11.84	11	38.39	15.92
0.3±0.001	60.14	13.63	10.37	13	36.85	15.28

4. Conclusion

Analyzing the results of calculations for fine-grained products of various thicknesses, the following can be noted: the thickness of the product affects not only the quantitative characteristics of heat release, but also changes its kinetics. It has also been established that the thicker the product, the more heat is released in absolute units and the greater its share in the total amount of heat for heating. This is easily explained by the fact that with an increase in the thickness of the product in terms of the specific area of the heated surface, an increase in the volume of the product is also observed. At the same time, it should be noted that there will no longer be such a direct dependence on the specific volume [10, 11].

Thus, the calculation of the actual economic efficiency from the introduction of environmentally acceptable technology allowed the Namangan house-building plant to save energy and expensive cement, and also made it possible to use man-made waste, which improved the environmental condition in the Fergana Valley.

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