ISBN(softcover): 978-3-0364-0398-4 ISBN(eBook): 978-3-0364-1398-3

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Key Engineering Materials
ISSN: 1662-9795, Vol. 953, pp 85-97
doi:10.4028/p-RwzP9p

Submitted: 2023-02-06
Accepted: 2023-05-03
Online: 2023-08-25

Research of Properties and Rational Composition of Ecosafe Building Materials with Ash-and-Slag Waste from Masute Fuel And Coal Combustion

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Keywords: ash-and-slag, solid waste, building material, environment protection technologies, granules of bulk, cement-sand mixture, strength, density.

Abstract. The study evaluates the method for determination of the rational technical and economic indicators, namely the rational composition and flexural strength, of building materials containing ash-and-slag obtained from heat-and-electric power plant as waste from the combustion of masute and coal. Results of method application were obtained. The study is aimed on reduction of the negative technogenic impact on the lithosphere by developing an appropriate environmental protection technology for utilization of the mentioned above waste as a replacement of sand in building materials made of cement-sand mixture. The rational composition of the building materials containing ash-and-slag waste granules was selected basing on the results of two stages of experimental research – mechanical bending tests of straight two-support beams on a rupture machine. It was proposed to provide a complex index for assessment of the efficiency of ash-and-slag waste disposal in the building materials, which refers to relation of the strength limit to the density of the material per unit value. The results of calculation of the index magnitudes were obtained.

Introduction

Today there is an inextricable link between the level of ecological safety (ES) of environmental components due to their pollution by various factors of man-made (technogenic) origin and the necessity to ensure heat and electrical energy consumption of large urban ecosystems, including industrial enterprises, housing and more. Importance of the factors of the population life quality, produced by mentioned above objects of the technosphere, raises attention to the problem of interaction of the sector of energy generating enterprises (in particular the manufacturer of heat and electrical energy – heat-and-electric (H&E) power plant (PP)), especially high capacity ones, and environmental components from the standpoint of important management and technical and technological decisions. High priority was given to increase of the use of natural resources, streamlining the extraction and enrichment of fossil fuels, its processing and combustion, processes and technologies of energy generation (electrical, heat, mechanical, etc.), as well as to improvement of the facilities providing access to the final consumer before the use of such energy. At current stage of development of heat energy manufacturing in Ukraine, the global problem of interaction between the environment and energy generating enterprises is relevant. In particular, this happens due to the pollution of the lithosphere with products of the main technological processes – ash-and-slag (A&S) solid waste, which is produced in large quantities and therefore requires large areas for storage in the form of dumps. Therefore, represented above considerations determine the relevance of the topic of the article.

Problem Formulation

The study was performed on the example of JSC "DTEK DNIPROENERGO", its separate divisions and PJSC "Dniprovska Teplotsentral" of Prydniprovska H&E PP (Dnipro, Dnipropetrovsk Oblast, Ukraine [1, 2]), which have a total planned electricity capacity of 1.765 GW and total planned heat capacity of 0.983 GW (400 millions kW·h per month) [3].

The issue of ensuring the compliance of the level of ES of manufacturing activities of any energy generating enterprise, in particular the manufacturer of heat and electrical energy – H&E PP, with the normatively established indicators is relevant and "pungent" in modern urban ecosystem. in the Solid waste pollution of such component of the environment as the lithosphere is regularly limited by area of organized landfills for their disposal and storage. Thus, the severity of the problem of placing of waste of manufacturing activities of such enterprises raises due to their large capacity, taking into account the total capacity of energy produced.

On the other hand, there is the question of the by-component composition of the granules of such pollutant. It is analyzed in source [3] and represented on Fig. 1.

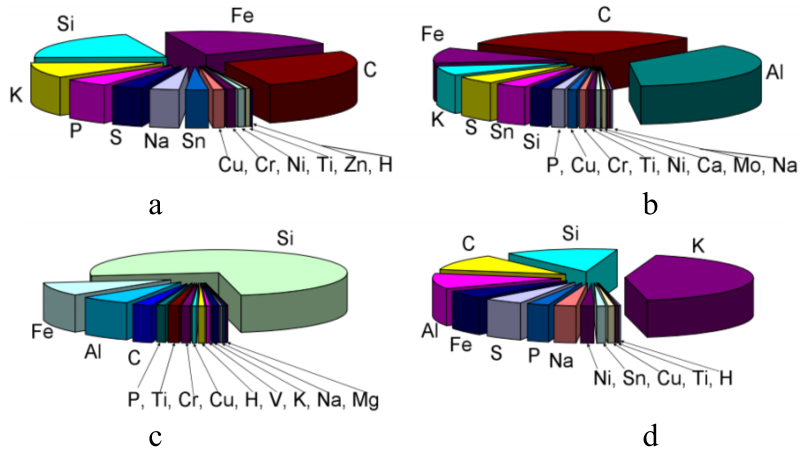


Fig. 1. Elemental composition of A&S waste samples of the Prydniprovska H&E PP, stored on ash dumps [3]: black opaque (magnetic) balls of different sizes (a); transparent colorless balls (b); white opaque «quartz-like» balls (c); irregularly shaped black secretions (d)

It may be seen, that in the composition of certain types of granule fractions, such as: a) black opaque (magnetic) balls of different sizes, b) transparent colorless balls, c) white opaque «quartz-like» balls and d) irregularly shaped black secretions, there are small amounts of heavy metals, but the bulk of the granules consists of silicon, carbon, aluminum, iron, potassium. There is also a significant amount of sulfur, phosphorus, sodium. Thus, it can be concluded that such A&S waste is not completely chemically safe, but the potential low chemical hazard is exacerbated by a large-scale factor. Then the most rational organizational and technical solution to reduce the anthropogenic load of this energy generating enterprise on the lithosphere will be the development of environmental protection technology (EPT) utilizing A&S granules as the component of the building material (BM).

Analysis of publications

On the basis of results of analysis of scientific, technical, reference, patent and regulatory literature we need to find the comprehensive solution of A&S granules waste disposal problems. The description and analysis of the ecological condition of the region of location of the energy generating enterprise selected for analysis – namely, Dnipropetrovsk region and the city of Dnipro, are given in the sources [1, 2]. Description and analysis of the structure, indicators of economic and manufacturing activity and impact on the environment of the JSC "DTEK DNIPROENERGO", its separate divisions and PJSC "Dniprovska Teplotsentral" of Prydniprovska H&E PP, are described in the source [3]. The theory of construction of EPT for environmentally hazardous technical energy generating facilities consuming carbon-containing non-renewable fuels is represented in the monograph [4]. Approaches to solving the problems of accumulation of solid waste from the manufacturing activities of industrial enterprises by developing of EPT and utilization of combustible waste as materials for fuel briquettes are given in the article [5]. Issues of high-temperature utilization of carbon-containing solid waste are covered in the study [6], the use of organic high molecular weight waste from the food industry are given in the study [7], features of the use of renewable fuel sources in energy-generating facilities are studied in the study [8], issues of reliable, rapid and low-cost detection of urban air pollution, including dust from bulk components of BM, are shown in the study [9]. The theory and examples of developing of ecological safety management systems (ESMS) based on relevant EPT, as the methodological basis for ensuring the legislative established level of ES, are described in the source [10]. Characteristics of traditional BM and methods of their determination are described in the manual [11], the theory of stress-strain state and mechanical testing of structural materials is given in the source [12], innovative approaches to ensuring the durability of BM are represented in the source [13]. There are studies on the use of special coatings [14] and impurities [15, 16] for BM in the construction of buildings and structures – namely, reinforced concrete [14, 15], steel trusses [17] and composite materials [16] – providing high stability at extreme and prolonged thermal exposure of fire [14, 15] changes in climatic conditions [18] and other sources of heat, such as technological processes [19], as well as special treatment of fittings and farm elements [20].

Thus, to ensure the solution of the problem of accumulation of large-scale bulk solid waste from coal and masute combustion, namely A&S produced by the PP and located in the metropolis, in this study we have developed EPT, which scheme is represented on Fig. 2. Its operation is based on the fact that A&S, unloaded from the furnaces of power units (position C in the scheme), is primarily transported for storing in storage (positions H and I in the scheme). Then it is transferred to the sorting station (position J in the scheme) with sieves divided in 3 fractions by size. The smallest fraction is transferred immediately to the consumer (position P in the scheme), and the middle and large fractions are crushed in crushers (positions K and L in the scheme) and transferred to the respective consumers (positions N and O in the scheme). A feature of the system is the ability to adjust the ratio of the produced fractions of A&S granules, depending on the specific order of consumers. It is achieved by the use of such by-products of the enterprise as a part of BM. So it allows to dispose A&S waste. Thus, the question of determination of the rational composition of such BM and its mechanical properties arises, which is the main purpose of the research outlined in this article.

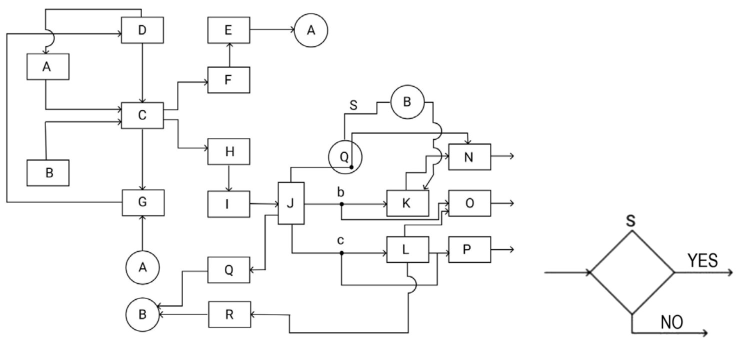


Fig. 2. Scheme of developed EPT for Prydniprovska H&E PP:
A – atmosphere, B – accumulation of coal, C – furnace of the power unit, D – cooling lake, E – exhaust gases cooler, F – exhaust gases purification system, G – heat energy consumer, H – A&S storage, I – storage of unsorted solid waste, J – sorting station, K and L – shredders for large and medium fractions, N, O and P – consumers of road crushed stone (large fraction), grain for concrete (medium fraction), sand for cement mixture and paving slabs (small fraction), Q and R – dust collectors, S – product requirements analyzers

Aim of Paper

The aim of the study is to determine and rational technical and economic indicators of BM containing A&S waste from H&E PP and develop the method for their determining as a material basis for EPT from negative technogenic impact on the lithosphere by means of utilization of such waste.

Object of the study is the complex of mass-size, technical and economic indicators of BM containing A&S waste from H&E PP, consuming coal and masute. Subject of the study is the set of dependences of values of object of the study to properties and content of utilized A&S waste.

Materials and Methods

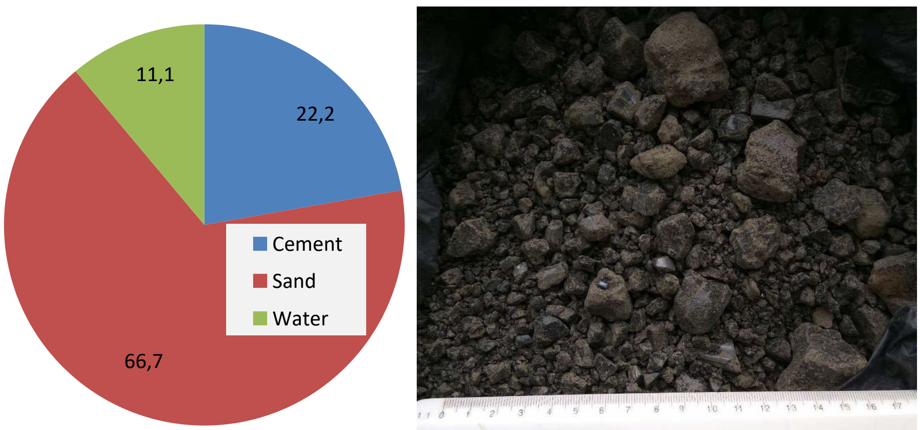
Materials studied in this article are solid ash-and-slag waste samples taken from H&E PP, consuming coal and masute, in cement-sand mixture (CSM). The compositions of the reference mixture for different variants were compared. Depending on the variant, such mixture contained different amount of A&S granules replacing the amount of sand, corresponding by weight, (8 different variants). As described by a pie chart on Fig. 3a, the basic CSM content is namely: a) cement – 1 mass part; b) sand – 3 parts by mass; c) water – 0.5 part.

Methods of the study are following: analysis of scientific, technical, reference, patent and regulatory literature; the main provisions of the disciplines "Environmental Protection Technologies", "Design and development of environmental safety systems", "Strength of Materials"; experimental research of mechanical properties of materials on laboratory rupture machine; size and mass research of fractions of bulk granules; least squares method.

Main part

Analysis of the composition and properties of cement-sand mixtures

The composition of general purpose CSM is as follows [11, 13]: a) cement – 1 mass part; b) sand – 3 parts by mass; c) water – 0.5 mass part. Thus, the total amount of 4.5 mass parts of 22.2 % is provided with cement, 66.7 % – with sand and 11.1 % with water. This composition is represented on Fig. 3. Composition of general purpose CSM is shown on Fig. 3, a. Appearance of A&S granules before grinding and preliminary sieving is prepresented on Fig. 3, b.



a b

Fig. 3. Composition of general purpose CSM [11, 13] (a) and appearance of A&S granules before grinding and preliminary sieving (b)

Indicators of strength of general purpose CSM are as follows [11, 13]: a) bending strength σ_{bs} = 6.0 MPa; b) compressive strength σ_{cs} = 30.0 MPa. The density of general-purpose CSM is ρ_c = 1910 kg/m^3 [11, 13].

Variants of the study

In the study we propose to utilize the A&S waste, pre-ground in a selected and calculated crusher and sifted on a developed sieve, as a replacement of part of the sand in the CSM the BM being made of. Since the maximum content of sand in the CSM of general purpose is up to 70 %, it is proposed to perform calculation study and experimental studies for 8 variants of the content of A&S granules *C*(A&S) in the BM, the parameters of which are summarized in Table 1 and on Fig. 4.

Table 1. Parameters of variants of the study

Variant	A	B	C	D	E	F	G	H
C(A&S), % mass	0	10	20	30	40	50	60	70

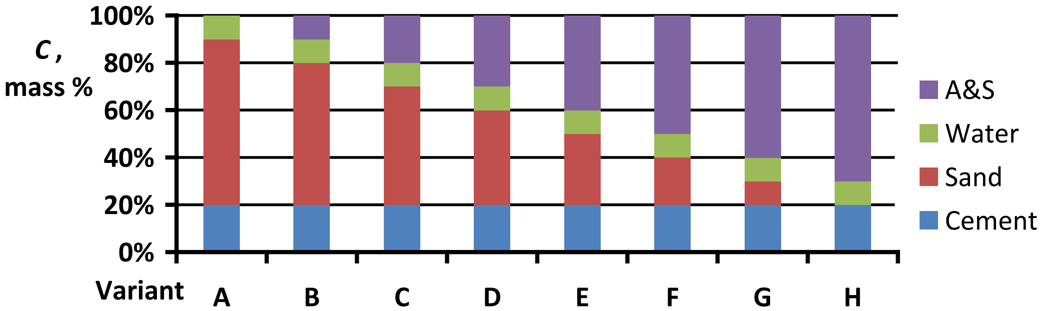


Fig. 4. Variants of the study

Determination of density of balk of ash-and-slag granules

To determine the bulk density ρ_b of A&S granules we have used the method when the granules filling the measuring container with a volume of W_1 are weighed to determine the mass m_1 of this sample by formula (1). To determine the apparent density ρ_a of A&S granules we have used the method when a sample of granules of mass m_2, obtained by weighing, is poured into a measuring container of volume W_0, filled with water of volume W_2, ($W_0 > W_2$), while the volume of water with a sample in the container increases by the value of ΔW (according to the measuring scale of the container – see formula (2). The value of the true density ρ_t of A&S granules is determined by formula (3), where m_3 is the mass of granules not taking into account the substance in their pores.

$$\rho_b = m_1 / W_1, \text{ kg/m}^3; \quad (1)$$

$$\rho_a = m_2 / \Delta W, \text{ kg/m}^3; \quad (2)$$

$$\rho_t = m_3 / \Delta W_1, \text{ kg/m}^3. \quad (3)$$

To determine the true, apparent and bulk density of the A&S granules, the experimental installation was designed and manufactured. The scheme of the installation is represented on Fig. 5. The mechanism of action of the experimental installation for determination of the true, apparent and bulk density of the A&S granules is following.

The apparent density of A&S granules is determined by the difference between the values of the Archimedes force and the corresponding depth of immersion of the measured floating container (item D on Fig. 5) without bulk on the ballast board (item E on Fig. 5) and with the bulk showing the pointer (item K on Fig. 5) on the vertical ruler (item I on Fig. 5). The weight of the bulk is determined by pre-weighing on the scales (pos. M on Fig. 5).

To determine the bulk density of A&S granules, the data on the volume of the measuring container and the average volume of the granules of the bulk are used. Herewith, the granules are conventionally geometrically modeled as ellipsoids of rotation. The data on the fractional composition of the bulk by the size of granules is taken according to the results of sorting on sieves (see Fig. 7) and multiple measurements of the overall dimensions of the granules from a sample set of 500 pcs., made with caliber (see Fig. 8).

When determining the true density of A&S granules, the measuring container is filled not only with a bulk of A&S granules, but also with water. This takes into account the change in water density depending on its temperature, measured with a thermometer (item L on Fig. 5).

The distribution of true density values of BM from general purpose CSM containing A&S granules ρ_{bm} on all variants of research is represented on Fig. 6,a. The density of dry cement is ρ_c = 3140 kg/m^3, water ρ_w = 1000 kg/m^3, dry sand of the middle fraction ρ_s = 1650 kg/m^3 [11, 13]. According to the results of 3-fold measurements, the average magnitude of density values was ρ_t = 1750 kg/m^3, ρ_b = 1250 kg/m^3 and ρ_a = 1450 kg/m^3 correspondingly. The relation between the values of true ρ_t, apparent ρ_a and bulk ρ_b density of A&S granules is represented on Fig. 6,b.

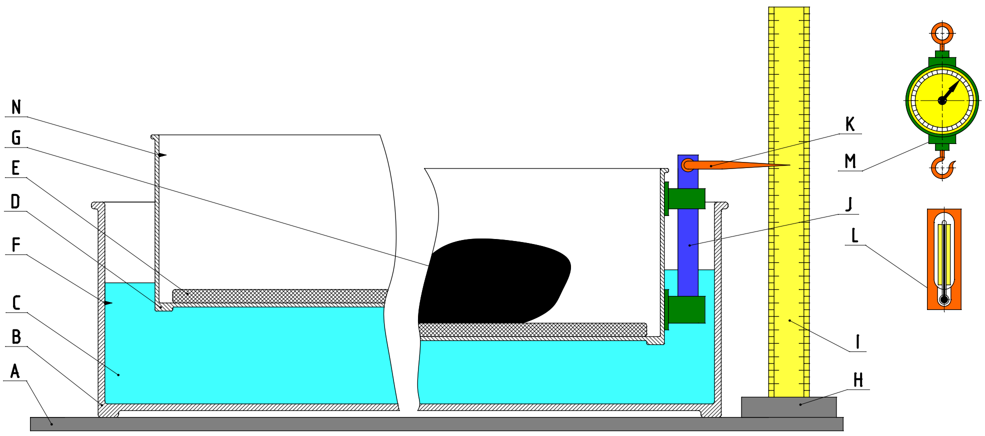
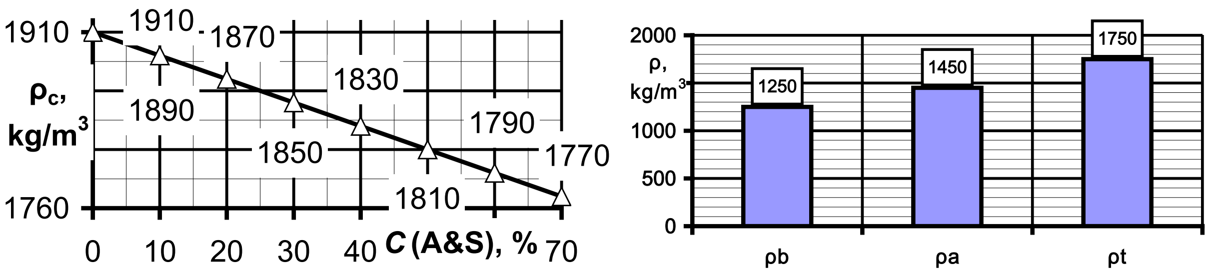


Fig. 5. Scheme of the experimental research of density of A&S granules balk waste
A – laboratory table; B – measuring stationary container; C – measuring fluid; D – measuring floating container; E – ballast board; F – mark of the measuring stationary container; G – object under study; H – basis of the ruler; I – ruler; J – holder; K – pointer; L – mercury thermometer; M – scales; N – mark of the measuring floating container



a b

Fig. 6. Distribution of magnitudes of density of general purpose CSM products containing A&S granules on research variants (a) and a ratio between values of true ρ_t, apparent ρ_a and bulk ρ_b density of A&S granules (b)

Experimental research of fractional composition of balk of ash-and-slag granules

To obtain the distribution of A&S granules by size groups for a sample set of N = 500 units, we have designed the sieve with replaceable steel woven mesh, differing in cell size, the sketch of which is shown on Fig. 7, b. All A&S granules have a convex irregular geometric shape and different sizes. To obtain data on their fractional composition by size groups, we have used the assumption that they have the shape of ellipsoids with the dimensions of the $x : y : z$ axes and the volume V (formula (4)). Granules of hyperboloid shape in the first approximation can be replaced with spheres of volume-equivalent diameter d, determined by formula (5) – see Fig. 7,a.

$$V = 4 / 3 \cdot \pi \cdot x \cdot y \cdot z, \text{ m}^3; \quad (4)$$

$$d = (6 \cdot V / \pi)^{1/3}, \text{ m}. \quad (5)$$

The distribution of magnitudes of the equivalent diameter of the A&S granules by size groups for a sample set of $N = 500$ units, obtained in absolute values by direct measurements with a caliber, is shown in the form of a histogram on Fig. 8, a. In relative terms – in the form of a graph – this distribution is shown on Fig. 8, b.

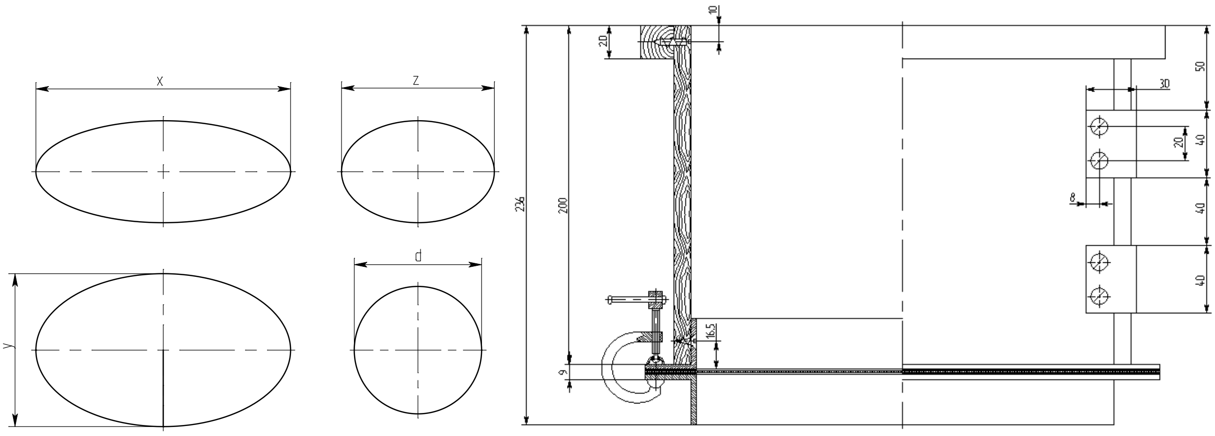


Fig. 7. Geometric parameters of ellipsoid and sphere with equivalent diameter (a), sieve sketch (b)

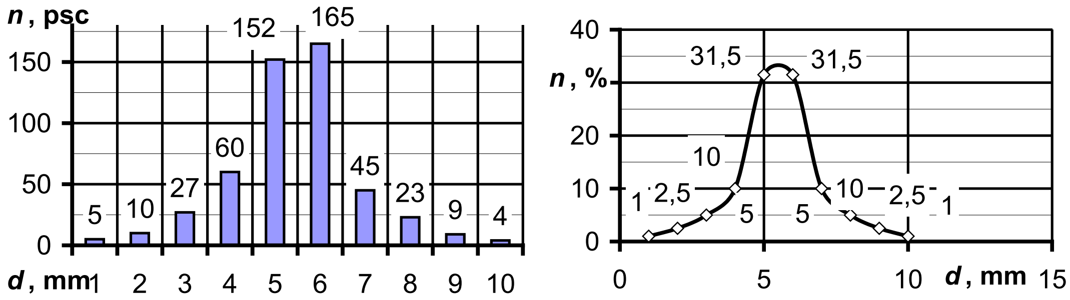


Fig. 8. Distribution of absolute (a) and relative (b) magnitudes of the equivalent diameter of the A&S granules by size groups obtained for the sample set of $N = 500$ units

Determination of geometrical parameters of experimental layouts of building material containing ash-and-slag waste

The geometric shape of BM products is a rectangular parallelepiped (for sketch of the product see Fig. 9, a). The ratio of its main dimensions (a – height; b – width; c – length) is the same as that of ordinary brick: $a : b : c = 0.25 : 0.5: 1.0$, i.e. there is a interrelation shown with the formula (6).

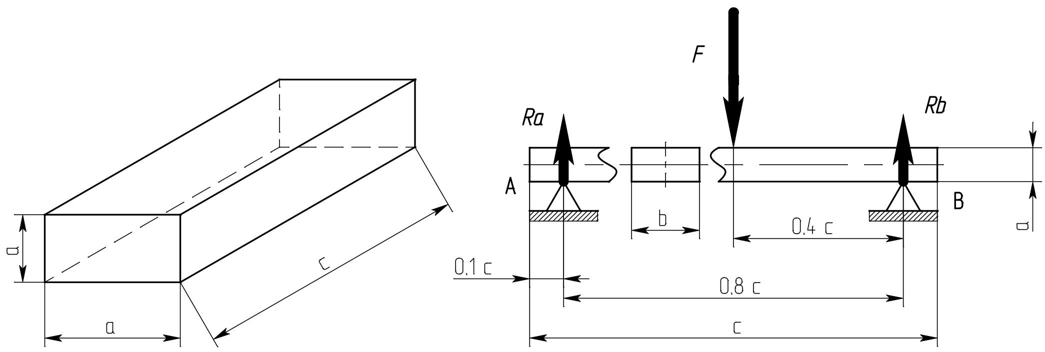
$$c = 2 \cdot b = 4 \cdot a. \tag{6}$$

Obtaining magnitudes of mechanical properties of products of BM containing A&S granules was performed in the study by means of mechanical tests on the bending of the two-support beam. The loading scheme of the experimental sample is shown on Fig. 9, b.

The test was carried out on a specially equipped laboratory bursting machine DM-30M, which is located in the complex laboratory of hydraulics and EPT of the Department of Applied Mechanics and Environmental Protection Technologies of NUCD of Ukraine of SES of Ukraine, has a muscle drive and develops maximum force of $[F] = 3$ kN.

To determine the rational magnitudes of dimensions of the experimental samples of BM products a design calculation was performed based on the theory of discipline “Strength of Materials” [12].

The bending strength of a two-support straight beam is determined by formula (7), and for its components – by formulas (8)–(11). Then formulas (8) and (9) take the form of formulas (12) and (13). Then, taking into account the fact that the maximum force developed by the breaking machine in the work will be limited to the value of $[F_1] = 1.5$ kN, we have obtained formula (14) to determine the size a. After substituting the initial data into the formula (14) we have the following results: a = 35 mm, b = 70 mm and c = 140 mm.



a b

Fig. 9. BM product sketch (a) and BM product sample loading diagram for bending mechanical properties tests (b)

$$\sigma_{max} = M_x / Wx, \text{MPa}; \quad (7)$$

$$W_x = I_x / Y_{max}, \text{m}^3; \quad (8)$$

$$M_x = F \cdot 0.4 \cdot c, \text{N·m}; \quad (9)$$

$$I_x = b \cdot a^3 / 12, \text{m}^4; \quad (10)$$

$$Y_{max} = a / 2, \text{m}; \quad (11)$$

$$W_x = b \cdot a^2 / 6, \text{m}^3; \quad (12)$$

$$\sigma_{max} = 4.8 \cdot F / a^2, \text{MPa}; \quad (13)$$

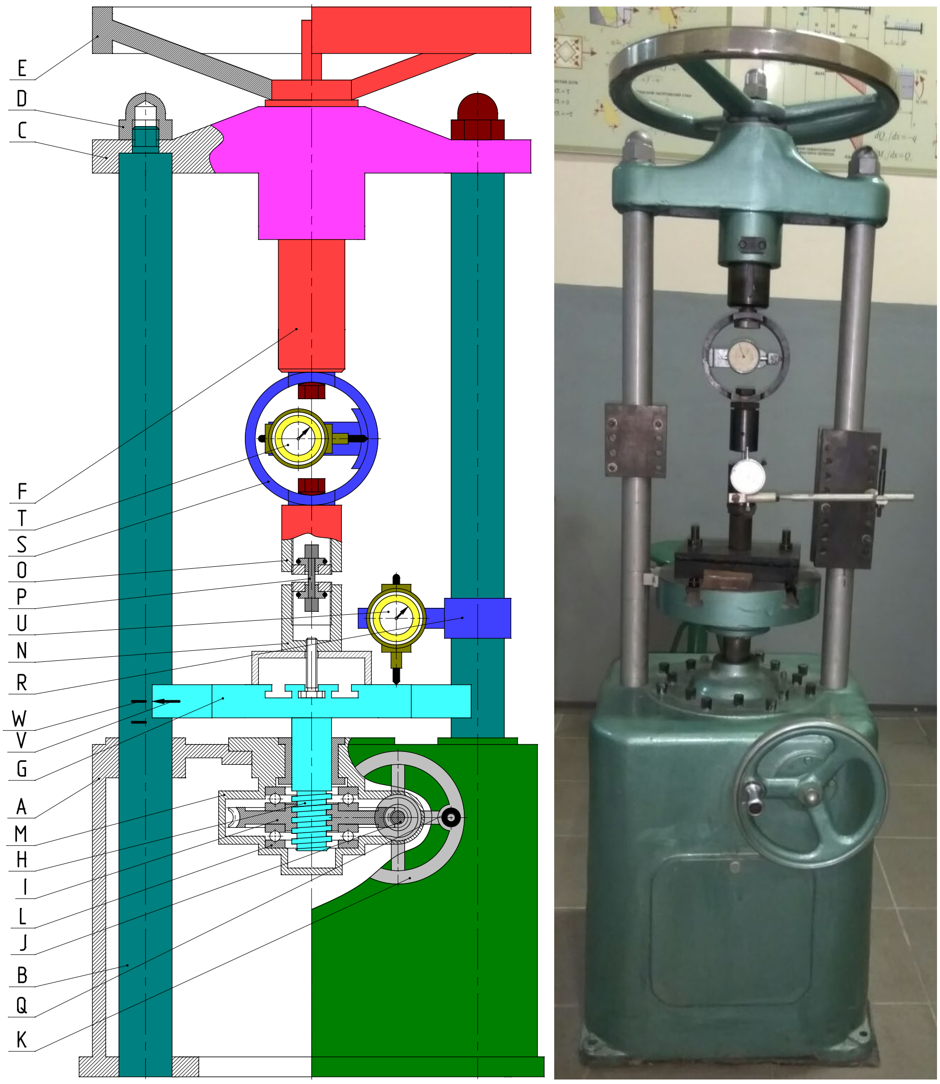
$$a = (4.8 \cdot [F_1] / \sigma_{max})^{1/2}, \text{m}. \quad (14)$$

The scheme of the bursting machine and its appearance are shown on Fig. 10. The dynamometer of the bursting machine and the scheme of its operation are shown on Fig. 11.

The appearance of experimental samples of BM is represented on Fig. 12, a. The appearance of the form for manufacturing of experimental samples is shown on Fig. 12, b. The experimental sample installed on the loading device of the bursting machine is shown on Fig. 12, c. The appearance of the fracture of the experimental sample containing A&S granules after destructive mechanical bending test is shown on Fig. 12, d.

To select the rational composition of the BM containing A&S granules from among the above variants, two stages of experimental research were planned and carried out, during which mechanical tests of experimental samples of selected shape and size for bending strength of straight double beams were performed on the bursting machine.

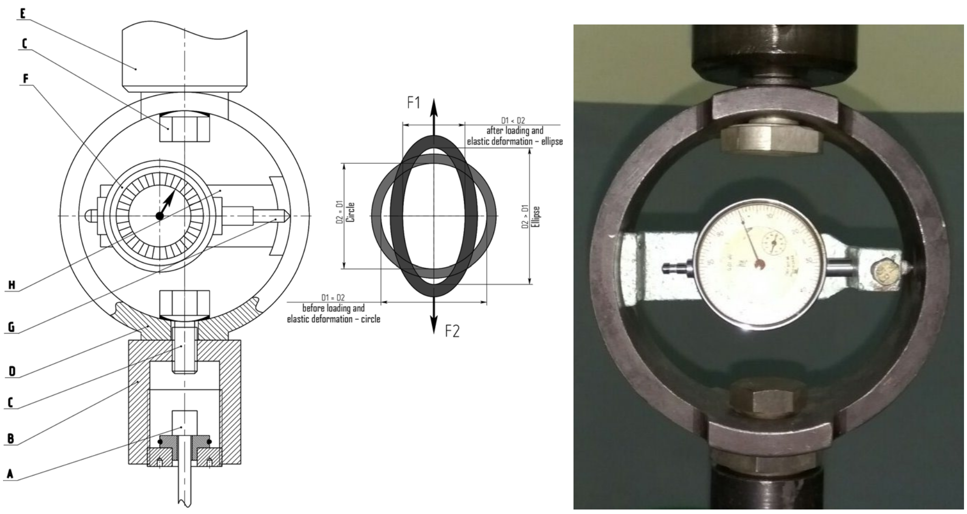
The results of the first stage of the experimental research for all variants of the composition of BM products containing A&S granules are represented on Fig. 13, a. Their analysis have shown that the flexural strength of such material, where the part of the sand is replaced with the A&S granules, first increases from the value for pure CSM (3.9 MPa) up to a maximum of 8.5 MPa at a A&S granules content of 40 %. Then it decreases down to a minimum of 3.1 MPa with complete replacement of sand on the secondary, when content of A&S granules is 70 %.



a b

A – bed; B – column; C – traverse; D – nut column; E – flywheel of fixed support; F – fixed support; G – table; H – lead screw; I – worm wheel with running nut; J – worm; K – flywheel drive table; L – bearing; M – gearbox housing; N – lower grip; O – upper grip; P – sample; Q – flywheel handle; R – holder of the table movement indicator; S – dynamometer; T – dynamometer indicator; U – table movement indicator; V – label on the table; W – labels of the extreme positions of the table

Fig. 10. Bursting machine: scheme (a) and appearance (b)



A – sample; B – threaded cup; C – mounting screw; D – dynamometer bracket; E – fixed support of the bursting machine; F – watch-type indicator; G – indicator leg; H – indicator mounting

Fig. 11. Elements of the bursting machine: dynamometer (a) and its operation scheme (b)

In the second stage of experimental research the samples of BM products with a rational composition, determined in the first stage (40 % of the A&S granules), were subjected to mechanical tests after 1–7 days exposure to complete the chemical and phase transformations and set the final strength. The results of the second stage of experimental research for such variants of the duration of exposure of BM products containing A&S granules are illustrated on Fig. 13, b. It shows that with increasing duration of exposure the strength of the sample of BM material increases correspondingly from 8.5 MPa at the exposure of τ = 1 day up to 11.0 MPa at the exposure of τ = 7 days. With the following exposure the growth of strength values slows down and should go "on the shelf". Graphs on Fig. 13 are obtained by means of the least squares method in the form of polynomials of the 2nd degree, which are described with formulas (15) and (16).

$$\sigma(\tau = 1\ \text{day}) = -3.8\cdot 10^{-3}\cdot C(A\&S)^2 + 0.26\cdot C(A\&S) + 3.64,\ \text{MPa}; \quad (15)$$

$$\sigma(C(A\&S) = 40\ \%) = -4.17\cdot 10^{-2}\cdot \tau^2 + 0.75\cdot \tau + 7.79,\ \text{MPa}. \quad (16)$$

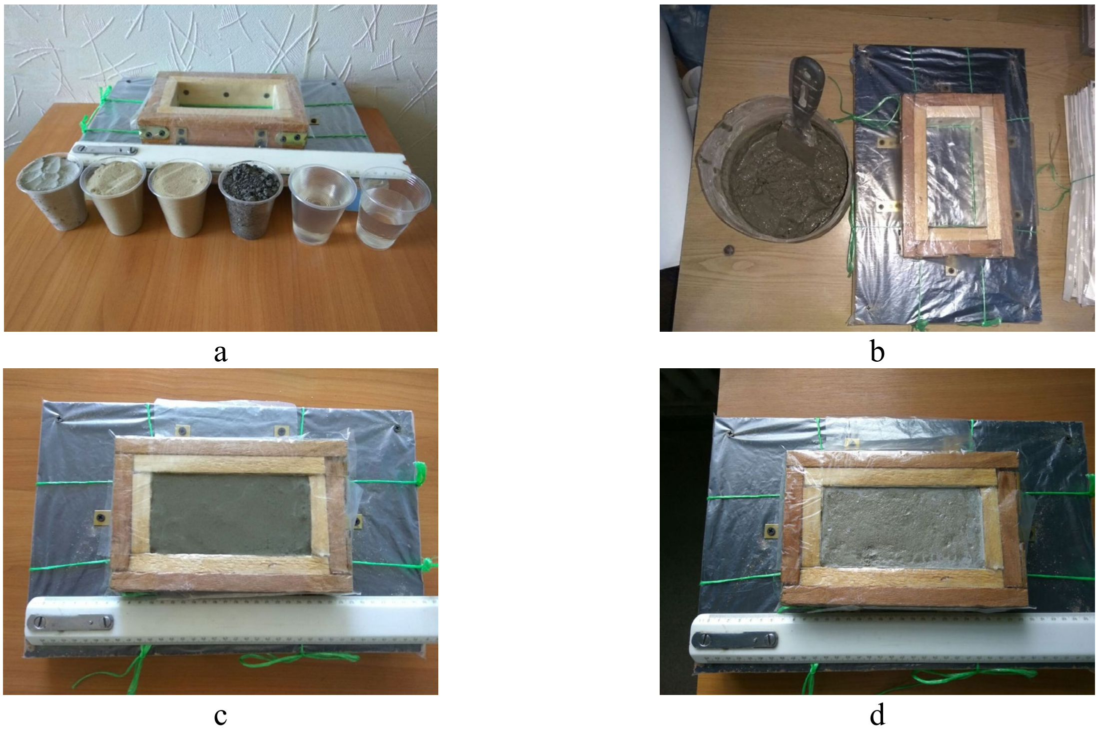


Fig. 12. Aspects of manufacturing and mechanical testing of experimental samples of BM containing A&S granules

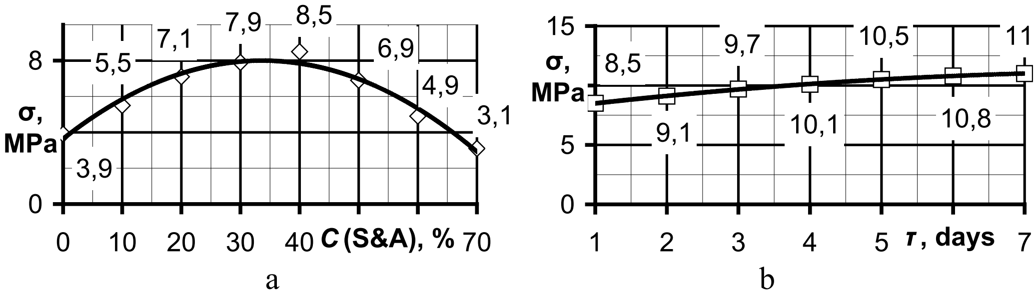


Fig. 13. The results of the first (a) and second (b) stages of the experimental research

Development of the Index of efficiency of utilization of ash-and-slag waste in composition of building material

To provide a complex assessment of the proposed method of reducing of anthropogenic negative impact on the lithosphere and, accordingly, to access the developed EPT, the corresponding index of A&S utilization in the BM I_{EM}, described by formula (17), was proposed in this study.

$$I_{EM} = \sigma_{max} / (\rho_{bm} \cdot P_{\$}) \cdot 10^3, \text{ kJ/\$}. \quad (17)$$

where σ_{max} – flexural strength of the material, MPa; ρ_{bm} – material density, kg/m^3; $P_{\$}$ – mass unit price of material, \$/kg.

The mass unit price of Portland cement PC-400 is \$ 0.07, the mass unit price of sand is \$ 0.01, and the mass unit price of technical water for legal entities is \$ 0.02. Therefore, the mass unit price of such BM of products from pure CSM is equal to \$ 0.1.

The mass unit price of A&S granules, taking into account the cost of its removal from the furnace, transportation to the dump and lease of land under the dump, as well as mechanical grinding and sorting operations is equal to \$ 0.02, i.e. 5 times less than BM of pure CSM.

The results of calculating of the values of I_{EM} index for both stages of the experimental research are illustrated on Fig. 14,a,b and described by means of the least squares method with polynomials of the 2nd degree – formulas (18) and (19).

The results of calculating of the values of δI_{EM} effect for both stages of the experimental research are illustrated on Fig. 14,c,d and described by means of the least squares method with polynomials of the 2nd degree – formulas (20) and (21).

$$I_{EM}(\tau = 1 \text{ day}) = -2.02 \cdot 10^{-2} \cdot C(\text{A\&S})^2 + 1.36 \cdot C(\text{A\$S}) + 19.04, \text{ kJ/\$}; \quad (18)$$

$$I_{EM}(C(\text{A\$S}) = 40\ \%) = -0.22 \cdot \tau^2 + 3.95 \cdot \tau + 40.91, \text{ kJ/\$}; \quad (19)$$

$$\delta I_{EM}(\tau = 1 \text{ day}) = -9.88 \cdot 10^{-2} \cdot C(\text{A\&S})^2 + 6.67 \cdot C(\text{A\&S}) - 6.74, \%; \quad (20)$$

$$\delta I_{EM}(C(\text{A\&S}) = 40\ \%) = -0.49 \cdot \tau^2 + 8.84 \cdot \tau - 8.40, \%. \quad (21)$$

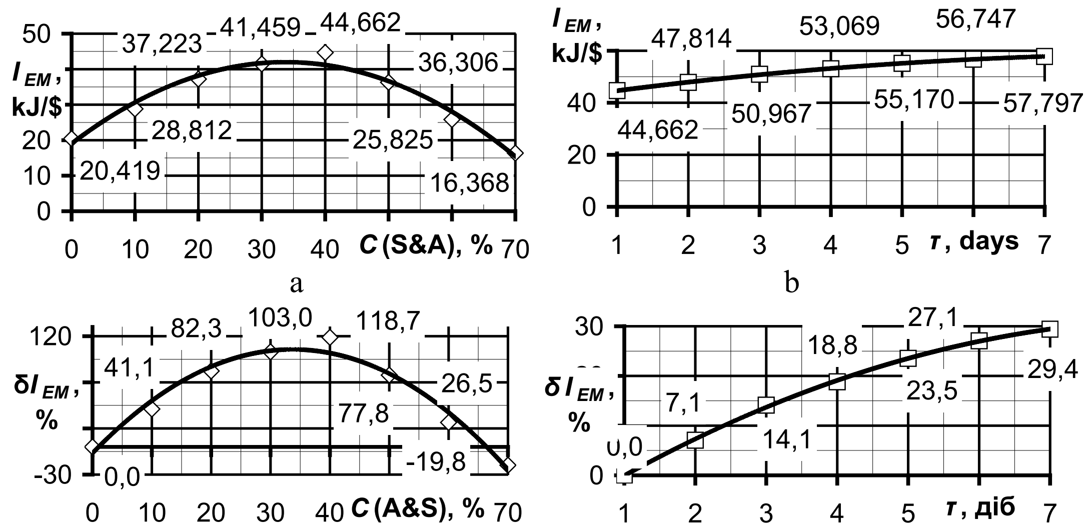


Fig. 14. The results of determining of the I_{EM} index (a, b) and its relative change (effect) δI_{EM} (c, d) for first (a, c) and second (b, d) stage of the experimental research

Conclusion

Thus, in this study, a method for determining the rational technical and economic indicators of building materials containing ash-and-slag as waste from the combustion of masute and coal at a heat-and-electric power plant with a capacity of 1.7 GW, namely the rational composition and flexural strength, was developed. The results of method application were obtained. Such studies are aimed at reduction of the negative man-made impact on the lithosphere by developing an appropriate environmental protection technology.

The analysis of the composition and properties of cement-sand mixture was performed, 8 variants of research study of ash-and-slag waste utilization as replacement of sand in building materials from cement-sand mixture, namely from basic to complete replacement, are offered. The values of bulk and apparent density of bulk from ash-and-slag waste granules and the true density of products containing ash-and-slag waste for all variants of its content are determined. Experimental determination of the fractional composition of ash-and-slag waste granules, presented as hyperboloids and spheres with equivalent diameter, was performed. A sieve with variable woven mesh of different cell sizes was designed for classification of ash-and-slag waste granules. The geometrical parameters of experimental samples of products containing ash-and-slag were determined according to the method developed on the basis of the provisions of the scientific-applied discipline “Strength of Materials”. The geometric shape of the samples is a rectangular parallelepiped with dimensions a = 35 mm, b = 70 mm and c = 140 mm.

The rational composition of the building materials containing ash-and-slag waste granules was selected according to the results of two stages of experimental research – mechanical bending tests of straight two-support beams on a rupture machine. It was found that the flexural strength of such building materials, when certain part of the sand in the cement-sand mixture was replaced with the ash-and-slag waste granules, initially increased from the value for pure cement-sand mixture to a maximum of 8.5 MPa obtained for an ash-and-slag waste content of 40 %. Yet it was found that for samples with same composition the strength of the sample material after exposure of 1–7 days increases by 1.5 times.

It was proposed to provide a complex assessment of the efficiency of ash-and-slag waste disposal in the building materials with the index of efficiency of ash-and-slag waste disposal in the building materials I_{EM}, which refers to relation of the strength limit to the density of the material per unit value. The results of calculation of the index magnitudes for all research variants in both absolute and relative values were obtained.

Scientific novelty of results of the study. For the first time the method of definition of rational technical and economic indicators of building materials containing ash-and-slag waste of heat-and-electric power plants as the material basis of environment protection technology from negative technogenic influence on lithosphere by utilization of such waste is offered.

Practical value of results of the study. The proposed method is suitable for streamlining the composition of such materials provided with the samples of different types of solid waste. Thus it increases the regulatory level of ecological safety of industrial and economic activities associated with coal and masute, as well as ash-and-slag dumps.

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