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SMALL-PIECE SEMI-DRY-COMPACTED CONCRETE PRODUCTS BASED ON WASTE FROM ENERGY GENERATING ENTERPRISES

The article investigates the fly ash from Burshtyn TPP for its use as a component of binding raw material compositions for the production of small-piece concrete products. Based on the integrated characteristics of chemical and phase composition, it was found that the ash is ultra-acidic, is an amorphous substance and is characterized by low hydraulic activity. Calcium-containing additives (slag cement and/or hydrated lime) and an alkaline aggregate (soda solution) were used to activate the ash glass. The charges compositions using ash at the level of 75–90 wt. %, in which the type and amount of activator and the type of aggregate (alkaline solution or water) were subject to variation in order to optimize the technological parameters of the materials. For materials formed at a pressing pressure of 25 kgf/cm^2 and hardened under steaming conditions, a positive effect of cement, alkaline aggregate and combined hardening activator on the properties of materials, their appearance and geometric dimensions was established. Such materials have a low level of mechanical properties; only certain charge compositions allow for a mechanical strength grade of M50 to M75. In order to improve the final mechanical strength of materials, the influence of pressing pressure, moulding moisture and hydrothermal treatment methods (steaming or parboiling) on the properties of materials of individual compositions was investigated. It has been determined that increasing the pressure up to 300 kgf/cm^2 and autoclave treatment of semi-finished products can significantly improve the level of mechanical properties. The rational compositions of binder compositions with a high degree of fly ash use (75 and 77 wt. %) were determined, on the basis of which water-resistant samples of asphalt concrete grades M 125 and M200 in terms of mechanical strength and grade F25 in terms of frost resistance were obtained by semi-dry pressing. The materials are recommended for the manufacture of products for the construction of sidewalk elements, as well as wall small-piece concrete products.

Key words: industrial waste; fly ash; production of fly ash concrete; hardening activators; hydrothermal treatment; semi-dry pressing; materials for road construction; wall concrete products

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ДРІБНОШТУЧНІ БЕТОННІ ВИРОБИ НАПІВСУХОГО ПРЕСУВАННЯ НА ОСНОВІ ВІДХОДІВ ЕНЕРГОГЕНЕРУЮЧИХ ПІДПРИЄМСТВ

Досліджено золу-виносу Бурштинської ТЕС на предмет її використання як компонента в'яжучих сировинних композицій для отримання дрібноштучних бетонних виробів. За інтегральними характеристиками хімічного і фазового складу встановлено, що зола є надкислою, являє собою аморфну речовину і характеризується низькою гідравлічною активністю. Для активізації зольного скла використані кальційвмісні добавки (шлакоцемент та/або гідратне вапно) та лужний затворювач (содовий розчин). Розроблені шихтові склади композицій з використанням золи на рівні 75–90 мас. %, в яких з метою оптимізації технологічних параметрів отримання матеріалів варіюванню підлягали вид і кількість активізатора, тип затворювача (лужний розчин чи вода). Для матеріалів, сформованих за тиску пресування 25 кгс/см^2 та які тужавіли в умовах пропарювання, встановлений позитивний вплив цементу, лужного затворювача і комбінованого активізатора тужавіння на властивості матеріалів, їх зовнішній вигляд і геометричні розміри. Такі матеріали мають невисокий рівень механічних властивостей, лише окремі шихтові склади дають змогу забезпечити марку за механічною міцністю М50 – М75. З метою покращення кінцевої механічної міцності матеріалів досліджено вплив тиску пресування, формувальної вологості і способів гідротермальної обробки (пропарювання чи запарювання) на властивості матеріалів окремих складів. Визначено, що збільшення тиску пресування до 300 кгс/см^2 та автоклавна обробка напівфабрикатів дозволяють суттєво покращити рівень механічних властивостей. Визначені раціональні склади в'яжучих композицій з високим ступенем використання золи-виносу (75 і 77 мас. %), на основі яких методом напівсухого пресування отримані водостійкі зразки золобетону марок М 125 і М200 за механічною міцністю і марки F25 за морозостійкістю. Матеріали рекомендовані для виготовлення виробів для будівництва елементів тротуарів, а також стінових дрібноштучних бетонних виробів.

Ключові слова: техногенні відходи; зола-виносу; виробництво золобетонів; активізатори тужавіння; гідротермальна обробка; напівсухе пресування; матеріали для дорожнього будівництва; стінові бетонні вироби

Introduction. The ever-increasing consumption of resources is closely linked to the problem of increasing waste production, i.e. waste generation at such an intensity that the volume of waste exceeds the capacity for its recycling or disposal. The National Waste Management Strategy for Ukraine until 2030 [1] points to real threats to Ukraine's environmental, anthropogenic, man-made and, ultimately, national security that have reached their critical point. The reasons that led to these threats are as follows: irreversible withdrawal of natural resources, exponential growth of waste generation and accumulation, and lack of effective technologies for their reuse. The approved Waste Management Strategy in Ukraine emphasizes the need to introduce a new paradigm of post-industrial social development, which primarily involves considering waste as a source of secondary material and energy resources.

For the production of binder-based construction materials, ash and slag waste from power generating enterprises has a significant resource potential, which is usually used as fertilizer in agriculture, in the production of lime-ash and lime-slag cements, slag pumice and slag wool, glass tiles, and as concrete aggregates. The studies of foreign scientists on the problem of utilization of large-tonnage industrial waste present technological solutions for the use of fly ash (so-called light ash) and coal ash (heavy ash) in the technologies of various types of binders, including composite and hybrid cements [2–8]. Domestic researchers of this waste group point to the prospects of using TPP fly ash in binder technologies as a component of raw material mixtures, as a filler for construction materials, and as a porosizer in the manufacture of structural and thermal insulation ceramics [9–12]. According to statistical data, fly ash is generated

in Ukraine in large quantities: 11539 tons (2018), 7187 tons (2019), 7674 tons (2020) [13], but despite the obvious benefits of using fly ash, the volume of its utilization in our country does not exceed 10 % [5], in the European Union it is more than 50 %, and governments at the state level stimulate its use [6]. Taking into account the large amount of generated and stacked ash waste in Ukraine, which remains after the destruction of thermal power plants by the aggressor country, as well as the positive results of its use in cement and concrete technology, such waste has broad prospects when considered as secondary raw materials for hybrid and composite cement technologies, alkali-activated binders.

Article purpose – study of fly ash from the Burshtyn thermal power plant of Ukraine as the main component of raw material mixtures for the production of small-piece concrete products for various purposes.

Theoretical justification on the choice of the material hardening mechanism. In this study, fly ash with the following established classification characteristics was investigated. The fly ash is low in calcium (CaO = 4,1 %), low in sulphate (SO_3 = 0,21 %), in terms of carbon content (2,5 %), it belongs to the first category. The Fe_2O_3 content in the ash is high (22,5 %). According to such integral characteristics of the chemical composition of ash as the basicity module (M_o = 0,06), it is classified as super acidic waste, and according to the quality factor (K = 0,5), it is classified as chemically inactive (for chemically active waste, K is > 1). According to the thermal analysis carried out on a synchronous thermal analyzer STA 402 PC to a temperature of 650 °C and subsequent cooling, the ash is thermally inactive, as evidenced by the absence of any thermal effects on the DTA curves. There are also no 'quartz' transitions, which indicates the amorphous form of SiO_2 in the ash. It can be concluded that the ash does not contain any crystalline quartz residues and is an amorphous substance, which is also indicated by the very low M_o value.

According to the literature, it is the amorphous phase that is characterized by binding ability when interacting with a wet environment, while the crystalline phase is inert in this process [14]. The hydraulic activity of the glass phase is determined by the Al_2O_3/SiO_2 ratio – the higher the ratio, the better the process of ash glass hydration. In this case, Al_2O_3/SiO_2 = 0,4, which is insufficient for the chemical activity of the ash glass phase. It is also known that ash glass is not hydrated at all in a neutral environment, but can exhibit hydraulic activity in alkaline or sulfate-alkaline environments. Therefore, since the experimental ash has low hydraulic activity and cannot solidify on its own under normal conditions, it is necessary to apply specific methods of influencing the ash glass to ensure the required solidification and structure formation of the future material.

In order to select effective methods of chemical influence on the amorphous phase of ash and its conversion to a hydraulically active state, the mechanisms of hardening of pozzolanic and slag cements, as well as certain types of clinkerless binders, deserve special attention. The hardening of pozzolanic cements is based on pozzolanization reactions (reactions of formation of $CaO{\cdot}SiO_2{\cdot}H_2O$ (CSH), $CaO{\cdot}Al_2O_3{\cdot}H_2O$ (CAH), $2CaO{\cdot}Al_2O_3{\cdot}SiO_2{\cdot}8H_2O$ (C_2ASH_8) or $2CaO{\cdot}Al_2O_3{\cdot}SiO_2$ and hydrogarnets of variable composition $3CaO{\cdot}Al_2O_3{\cdot}xSiO_2(6\text{-}2_x)H_2O$. In the presence of iron oxides, calcium hydroferrites or hydroalumina can also form. The formation of these binders occurs through the direct interaction of $Ca(OH)_2$ with SiO_2, Al_2O_3, radicals of dehydrated clay minerals $Al_2O_3{\cdot}2SiO_2$ (AS_2), which are present in mineral additives either in an amorphous and therefore more active form or in an amorphous form in the form of aluminosilicate glass. Such additives containing active SiO_2, Al_2O_3, AS_2 or aluminosilicate glass are both natural substances (opoka, diatomite, volcanic ash) and artificial (metallurgical slags, fuel ash and slag). Regarding the mechanism under consideration, it should be noted that all hardening products contain CaO, which is the main participant in pozzolanization reactions, and its content in the raw material mixture is ensured by the use of Portland cement clinker and gypsum in the production of pozzolanic cement and air or hydrated lime in the production of lime-pozzolanic cement. In this case, these additives act as a calcium-containing hardening activator.

In contrast to the hardening mechanism of pozzolanic cements, when new formations arise as a result of direct interaction of $Ca(OH)_2$ with amorphous SiO_2 and Al_2O_3, slag cement technology uses the 'slag awakening' effect. It consists in the fact that when a small amount of activators is added to slag glass, its thermodynamically unstable state is disturbed and its latent hydraulic properties are 'awakened'. This results in the restructuring of slag glass with the formation of CSH, CAH and other compounds with binding properties, which is accompanied by stone hardening. Activators in slag cement technology can perform the function of activators: CaO, Portland cement clinker, Na_2CO_3 and other alkaline substances (alkaline activators), gypsum or anhydrite (sulphate activators), lime and gypsum together (mixed activators).

Among clinkerless binders, the most interesting in this case are slag and ash binders, which are obtained by closing ash, ash and slag mixtures or simply slag (fuel or metallurgical) with a solution of an alkaline component. A prerequisite for the production of such binders is the presence of an amorphous aluminosilicate phase in the waste, which, like any aluminosilicate glass, is able to interact with alkalis under normal conditions. The glass phase is hydrolytically dissolved to form insoluble alkaline hydroaluminosilicates, which are not only more active than calcium compounds but also structurally stable, which gives the artificial stone greater durability compared to, for example, sulphate-slag cements. It is important that alkalis, unlike $Ca(OH)_2$, can interact not only with the vitreous phase of slag or ash, but also with crystalline compounds and amorphous AS_2 particles, forming the same alkaline hydroaluminosilicates. Therefore, two essential components must be present in the production of slag or ash binders - aluminosilicate

slag or ash glass and an alkaline component. For high-calcium slags and ashes ($M_o > 1$), any alkaline compounds that give an alkaline reaction in water can be used, for low-calcium slags and ashes only caustic alkalis (expensive NaOH or KOH) and soluble glass with a modulus of 0,5 ÷ 2,0. Non-silicate salts of weak acids (Na_2CO_3 or K_2CO_3) are more widely available, but can only be used in hydrothermal treatment of semi-finished products. To increase the basicity of the aluminosilicate component and its activity when using these salts, lime, Portland cement, or both are added to the mixture. It is important to note that for all the types of binders discussed above, hydrothermal treatment of semi-finished products is usually used. For steaming, hot air saturated with water vapour at atmospheric pressure is used, and for parboiling, the treatment is carried out at temperatures of 175–190 °C saturated water vapour under a pressure of 0,9 – 1,6 MPa in autoclaves. Hydrothermal treatment is especially important for amorphous components of binder compositions, whose solubility increases significantly with increasing temperature.

Having analyzed the above mentioned solidification mechanisms, it can be concluded that each of them can be applied to the experimental ash to a certain extent. To implement these mechanisms, the charge composition of binder compositions, in addition to the main material - ash, should contain Portland cement clinker and/or lime as hardening activators. The binder mixtures should be closed with an alkaline solution rather than water.

Experiment. Taking into account the above-mentioned mechanisms of fly ash glass hardening, the compositions of raw material binders were developed, which are given in Table 1.

The main principle used in the development of the blends was that all components of the blend should be involved in the process of quenching the material. Ash was used in its original state, with a specific surface area of 811 m^2/kg. To activate the ash glass, calcium-containing substances were used - slag cement P/A-S-400-N with a specific surface area of 464 m^2/kg (PJSC Ivano-Frankivskcement) and hydrated lime $Ca(OH)_2$ in the form of fluff. Soda ash Na_2CO_3 was used as an alkaline lime, the choice of which was due, firstly, to the greater efficiency of sodium lime as compared to potassium lime, and, secondly, to the fact that Na_2CO_3 is a part of large-tonnage waste from chemical production (production of Na_2S, alumina, caprolactam). It is known from the technology of slag and ash binders that the content of the alkaline component in the composition should be at least 2 % and not more than 5 % by weight of ash or slag (in terms of Na_2O). Calculations have shown that to meet the requirement for Na2O content of 2 wt. %, it is necessary to use an aqueous solution with a mass fraction of soda of 22 % (at a moulding moisture content of 12 %). To increase the raw strength of the semi-finished products, highly plastic clay with a plasticity number of 25 was added to some of the blends. To determine the effect of raw material components on the properties of the materials, the charge compositions were varied in a certain way, and the type of hardener (alkaline solution or water) was also subject to variation.

Table 1 – Charge composition of binding compositions

Charge code	Charge components, wt. %				Type of gating (moulding humidity 12 %)
	ash	slag cement	clay	hydrated lime $Ca(OH)_2$	
1s	87	10	3	-	22 % aqueous solution of Na_2CO_3
2s	77	20	3	-	22 % aqueous solution of Na_2CO_3
1sw	87	10	3	-	water
2sw	77	20	3	-	water
0sg	90	-	-	10	22 % aqueous solution of Na_2CO_3
1sg	85	10	-	5	22 % aqueous solution of Na_2CO_3
2sg	75	20	-	5	22 % aqueous solution of Na_2CO_3
1sgw	85	10	-	5	water
2sgw	75	20	-	5	water

Laboratory samples in the form of parallelepipeds measuring 70 × 35 × 17 mm were formed on a hydraulic press VP-500 with a specific pressure of 25 kgf/cm^2. Those charge compositions that showed the best results in terms of product properties at this stage of the study were later additionally moulded with a specific pressure of 300 kgf/cm^2. After moulding, the samples were hardened under different conditions. At the first stage, the samples were hydrothermally treated in a climate chamber for 15 hours, where the air temperature was constantly maintained at 75 °C and the humidity at 75 % (hereinafter ‘steaming’). After steaming, the samples were kept at a relative humidity of 90 % for 7 days on grids in closed desiccators with water poured on the bottom. Only after such exposure were the properties of the samples tested. At the second stage of the work, the samples were autoclaved at an industrial enterprise for the production of

silicate bricks (Kharkiv region). After the autoclave treatment, the samples were subjected to testing without further aging.

For all the samples, regardless of the setting conditions, their main properties were studied according to standard methods. The *density* of the samples after hardening was determined based on the weight and volume of the sample. The *mechanical strength* of the raw materials and hardening products was assessed by their tensile strength in bending (laboratory device MI-100 (NTU «KhPI»)) and compression (laboratory hydraulic press VP-500 (PLINFA)). The *water resistance* of the samples after curing was assessed by the softening coefficient K_r, which was determined by dividing the compressive strength of the sample in the water-saturated state (R_{sat}, MPa) by the compressive strength of the dry sample (R_{dry}, MPa). The material is considered water resistant if $K_r \geq$ is 0,75. The *freeze-thaw resistance* of the samples was assessed by the freeze-thaw resistance coefficient K_{mrz}, which was determined by dividing the compressive strength of the samples after 25 freeze-thaw cycles (R_{mrz}, MPa) by the compressive strength of the samples saturated with water for 3 days (R_{sat}, MPa). For frost-resistant materials, $K_{mrz} > 0,75$.

Experiment results and their discussion. The results of studying the properties of laboratory samples that were steamed are presented in Table 2.

Regarding the appearance of the samples, it should be noted that the samples containing cement as a calcium

Table 2 – Physical, mechanical, and operational properties of semi-finished and finished products that were cured in a climate chamber

Composition code and sample appearance*	Property indicators					
	product density, g/cm^3	strength limit			softening factor K_r	frost resistance coefficient after 25 test cycles K_{mrz}
		at compression of raw sample, MPa	when bending the product, MPa	under product compression, MPa		
1s	1,8	0,63	0,7	3,0	0,48	disruption
2s	1,9	0,75	2,5	4,9	0,85	0,80
1sw	1,7	0,60	0,5	1,8	not studied	not studied
2sw	1,8	0,65	1,2	2,5	not studied	not studied
0sg	1,6	0,60	0,4	2,3	0,70	0,40
1sg	1,8	0,60	1,8	5,8	0,75	0,90
2sg	1,9	0,65	2,2	7,0	0,75	0,75
1sgw	1,7	0,51	0,3	3,0	0,50	0,90
2sgw	1,8	0,56	0,5	3,9	0,60	1,00

Note*. Fill marks those samples that are defect-free and have an acceptable appearance.

activator, regardless of the curing conditions, were characterized by a uniform surface and a uniform grey color. For the samples obtained on the basis of blends containing 10 % cement, destruction of corners and individual faces was observed. At the same time, the samples of this group containing 20 % cement retained their shape. White specks were found on the samples of composition 0sg, which are probably represented by hydrated lime, which did not react due to insufficient moisture. In addition, the samples of this composition had defects in the form of chips and even surface peeling. The samples obtained from the mixtures with a combined activator (cement + lime) are characterized by the best appearance. It is important to note that the influence of cement is less pronounced on these samples in terms of appearance. Therefore, it can be concluded that samples of acceptable appearance can be obtained with 20 % cement for mixtures containing only cement activator and 10 % for mixtures containing a combined activator.

During the hardening of binders, there are always some changes in their volume and density, which occur due to the formation of compounds with different molar volumes and densities during hydration. Table 2 shows that the density values differ little from each other. However, there is a tendency for better compaction of materials (by 5 %) with an increase in the cement content in the compositions and when using an alkaline aggregate. The influence of cement is quite logical, given that it is the clinker component of the charge, as the most hydraulically active, that will be subject to hydration and hardening in the first place.

The highest compressive strength after hardening is characterized by samples obtained from blends with a combined activator (3–7 MPa), while for other materials this figure does not exceed 4,9 MPa. Also, any group of samples shows that with an increase in the cement content in the composition, their mechanical properties improve. Studies of mechanical properties have practically proved

the ineffectiveness of using water as filler: such materials have very low values of flexural and compressive strengths (1sw, 2sw, 1sgw, 2sgw). In general, it should be noted that the level of mechanical properties of the samples is low, which is explained by the small amount of moisture required for hardening, which is limited by the chosen moulding method. The significant dispersion of the components of the blends themselves, which does not allow for effective compaction of the semi-finished product at the stage of its formation, also does not contribute to the increase in mechanical strength. To some extent, this problem can be alleviated by using higher pressing forces than those used at this stage of the study, as well as by using a consolidating agent (e.g. sand). The use of clay as a binder at the moulding stage also did not produce the expected effect of strengthening the raw material, but instead worsened the mechanical strength of the hardening products. At the same time, even under the studied conditions, certain charge compositions of binding compositions make it possible to obtain materials with a mechanical strength grade of M50 (2s, 1sg, 2sg).

When studying the water resistance and frost resistance of materials (Table 2), it was found that most of them are characterized by the required water resistance (K_r > 0,75). At the same time, materials of compositions 1s, 1sgw and 2sgw have unacceptable water resistance. This may be due to the formation of water-soluble crystalline hydrates in the process of hardening, which adversely affects their mechanical strength in the water-saturated state. The programme for determining water resistance and frost resistance did not include materials of 1sw and 2sw compositions, which showed low mechanical properties. The dependence of frost resistance on the charge composition of the binding composition is more extreme than water resistance. In the first group of compositions (with cement activator), there is a clear tendency for this indicator to decrease with a decrease in the amount of cement. Similarly, the cement activator affects the frost resistance of materials containing a combined activator. It is noteworthy that the materials with lime activator (composition 0sg), despite their acceptable water resistance, turned out to be not frost-resistant. Given the significant influence of the structure factor on frost resistance, in particular porosity, this behavior of these materials can be explained by their increased porosity (the materials have the lowest density among all). Analyzing the frost resistance of the materials in interrelation with their appearance during or after the test, it can be noted that the samples of the first group of compositions (1s, 2s) containing 10 % cement had chipped corners and small fractures of the edges, which was not recorded on samples with 20 % cement. The materials with the combined activator had a good appearance after 25 test cycles, except for those obtained using water and 10 % cement.

Thus, analyzing the results of the studies carried out at this stage, it can be concluded that the materials are generally water resistant, with the exception of only three of the seven tested (1s, 1sgw and 2sgw). Most of the materials studied (five out of seven) can be assigned grade 25 in terms of frost resistance, while samples of compositions 1s and 0sg were not frost-resistant. Only two types of materials are characterized by a set of required properties, as well as an acceptable appearance: composition 2s (with cement activator) and composition 2sg (with combined activator). But they, like all the others, have low raw strength, which can be improved by applying higher pressing pressure and using lower moulding moisture. In addition, to increase the mechanical strength of the finished product, it would also be advisable to use an autoclave method of hydrothermal treatment (parboiling).

The second stage of the study was devoted to investigating the effect of these technological parameters on the properties of samples of compositions 2s and 2sg. The samples were pressed on a laboratory press at a specific pressure of 300 kgf/cm^2 and a moulding humidity of 10 %. Hardening of the moulded samples was carried out in industrial autoclaves for 10 hours at a temperature of 183 °C and a steam pressure of 1 MPa. To compare the effectiveness of hydrothermal treatment methods (steaming or parboiling), the samples were also hardened in a climate chamber under the same conditions as in the first stage of the study. Fig. 1 shows the appearance of the samples obtained under the above-mentioned conditions of moulding and hydrothermal treatment (in the photo, the letter ‘S’ means hardening of the material in a climate chamber (steaming), and the letter ‘P’ means in autoclaves (parboiling)). As can be seen from Fig. 1, the samples have the correct geometric dimensions and a defect-free appearance.

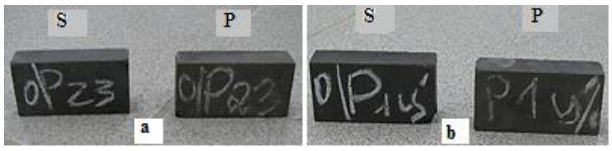

Figure 1 – Appearance of samples after hydrothermal treatment:
a – samples of composition 2s; *b* – samples of composition 2sg

The diagrams in Fig. 2 show the main properties of the test materials obtained under different pressing and curing conditions. The initial properties are given for the materials obtained at the first stage of the work – formed at a pressing pressure of 25 kgf/cm^2, moulding humidity of 12 % and steamed in a climate chamber.

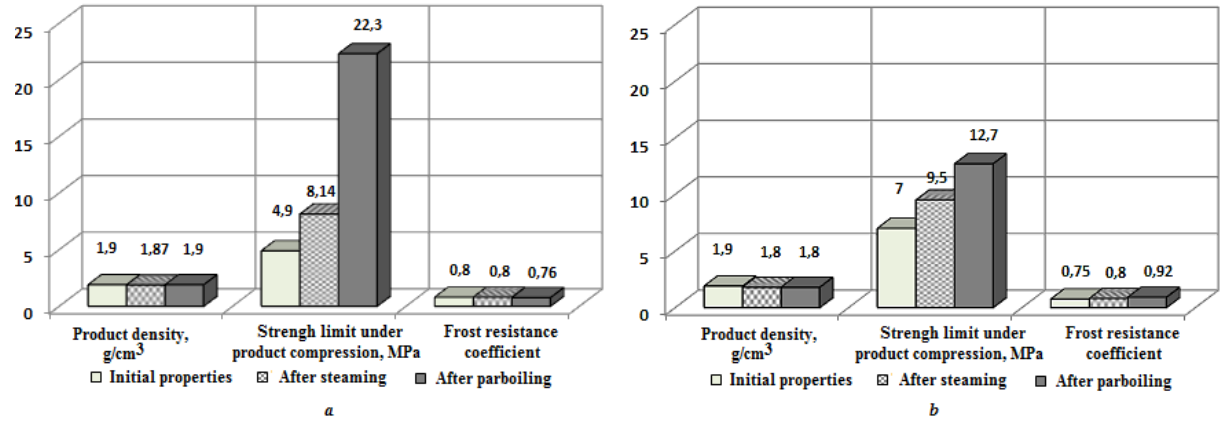

Figure 2 – Comparative characteristics of the properties of materials after curing under different conditions: *a* – materials of composition 2s; *b* – materials of composition 2sg

As for the raw strength of the semi-finished products and their density, the change in the technological parameters of the samples (pressing pressure and moisture content of the charge) had almost no effect on these properties, with changes occurring within ± 5%. Similarly, the level of frost resistance of materials of composition 2s remains almost unchanged, while in contrast, in autoclaved samples of composition 2sg, this indicator improves by 24 %, which allows us to predict a higher grade for their frost resistance. The 'structurally sensitive' property of curing products, mechanical strength, undergoes certain changes compared to the initial level of these properties. For example, an increase in pressing pressure leads to a noticeable improvement in the mechanical strength of materials. The increase in the mechanical properties of the samples when changing the conditions of hardening from processing in a climate chamber to autoclave processing is explained by the fact that steaming conditions produce a much larger amount of condensation moisture, which contributes to the activation of the hardening process. The diagrams in Fig. 2 shows that when parboiling was used, the mechanical strength of the hardening products increased by 2,7 times (samples 2s) and 1,3 times (2sg).

Analyzing the effect of semi-dry pressing conditions and hydrothermal treatment methods on the properties of materials in the complex, it should be noted that increasing the pressing pressure and autoclave treatment of semi-finished products leads to an improvement in the basic properties of materials, especially mechanical strength, on the basis of which it is possible to recommend such technological parameters for their production.

Conclusions. Based on the results of the study of the chemical and phase composition of fly ash, it was found that it is an amorphous substance of aluminous iron silicate composition and belongs to low-calcium, low-sulfate and superoxide ash. According to the values of the modulus of basicity (M_o = 0,09) and the quality factor (K = 0,5), the ash is a material with low hydraulic activity and is not prone to self-hardening under normal conditions.

Based on the analysis of the known mechanisms of hardening of pozzolanic, slag cements and clinkerless binders, a method of activating fly ash was chosen, which consisted of the use of activators (slag cement and hydrated lime separately and in combination) and an alkaline hardener (Na_2CO_3 solution). The properties of the samples obtained by semi-dry pressing of charges with a moisture content of 12 %, which contained ash in the amount of 75–90 wt. % and hydrothermally treated at atmospheric pressure. The samples have a raw strength that is at the level typical for silicate bricks (0,5 – 0,75 MPa). A positive effect of the cement component of the charge on the raw strength, density of materials after hardening, and geometry of the samples was revealed. The compressive strength of the samples (2,3–7,0 MPa) is at a low level, which is explained by the insufficient amount of moisture required for hardening, which is limited by the chosen moulding method. There is a tendency to improve the mechanical strength when using an alkaline hardener instead of water, slag cement in the amount of 20 % or a combined hardening activator (20 % cement, 5 % lime). The resulting materials are generally water-resistant, but only a few samples can be assigned the F25 frost resistance grade.

In order to improve the properties of the materials of two charge compositions (2s and 2sg), the effect of pressing pressure, moulding humidity, and hydrothermal treatment in an autoclave was studied. It was found that an increase in pressing pressure and a decrease in moisture content have almost no effect on the raw strength and density of the hardening products, but improve their final mechanical strength. Hydrothermal treatment in an autoclave leads to a significant improvement in the mechanical strength of materials. A rational composition of the charge (80 % ash, 20 % slag cement) was established, on the basis of which, at a specific pressing pressure of 300 kgf/cm^2, a mixture moisture content of 10 % and under the condition of hardening in an autoclave, materials with a raw strength of 0,75 MPa, a predicted grade for mechanical strength of M200 and frost resistance of 25 cycles can be obtained. The resulting materials can be recommended for the manufacture of curb and park stones, paving slabs, solid and hollow wall blocks and ordinary bricks.

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