

DEVELOPMENT OF SUSTAINABLE AERATED CONCRETE WITH ENHANCED ENERGY-SAVING PROPERTIES

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Annotatsiya: Uy-joy qurilishi hajmining oshishi yuqori samarali issiqlik izolyatsiyalash materiallarini ishlab chiqish, yaratish va o'rganishni talab qiladi. Zamonaviy qurilishda gazbetonning har xil turlari bunday qurilish materiallariga kiritilgan. Binolarning balandligi oshishi bilan strukturaning massasini kamaytirish dolzarb bo'lib qoladi.

Ma'lumki, 1200 kg / m³ zichlikdagi gazbetondan qurilgan devorning issiqlik o'tkazuvchanligi karbonat chiqindilari asosida gazbetondan qurilgan devorning issiqlik o'tkazuvchanligidan 4 baravar yuqori. Shunga ko'ra, bir xil issiqlik izolyatsiyasi quvvatiga ega bo'lgan devorlarni solishtirganda, biz ohaktoshdan qurilgan devorning qalinligi gazbetondan 4 baravar ko'p ekanligini ko'ramiz.

Bizning tadqiqotimiz gazbeton turlaridan biri - gazbeton karbonat chiqindilari asosida avtoklavsiz gazbeton olishga qaratilgan. O'tkazilgan tadqiqotlar shuni ko'rsatdiki, ustritsa ohaktoshidan toshlarni kesishda chiqindi sifatida hosil bo'ladigan nozik plomba moddasidan avtoklavsiz gazbeton olinadi, uning fizik-mexanik xususiyatlari normativ talablarga javob beradi. Karbonat chiqindilaridan foydalangan holda, o'rtacha zichligi 500 kg / m³ va quvvati 2,5 MPa gacha bo'lgan gazbetonli beton mahsulotlari olinadi, bu D500 in va B2 quvvat sinfiga to'g'ri keladi. Karbonatli chiqindilardan foydalanish va tsement iste'molini kamaytirish gazlangan betonning narxini 30% ga kamaytirishni ta'minlaydi.

Kalit so'zlar: Portlend tsement, gazbeton, karbonat chiqindilari, zichlik, o'ziga xos sirt maydoni, bosim kuchi.

Аннотация: Увеличение объемов жилищного строительства требует разработки, создания и изучения высокоэффективных теплоизоляционных материалов. В современном строительстве к таким строительным материалам относятся различные виды ячеистого бетона. С увеличением высоты зданий все более актуальной становится проблема снижения массы конструкции. Известно, что теплопроводность стены, возведенной из ячеистого бетона плотностью 1200 кг/м³, в 4 раза выше теплопроводности стены, возведенной из ячеистого бетона на основе карбонатных отходов. Соответственно, при сравнении стен с одинаковой теплоизоляционной способностью видим, что толщина стены, возведенной из известняка, в 4 раза больше, чем из ячеистого бетона.

Наши исследования направлены на получение безавтоклавного ячеистого бетона на основе карбонатных отходов, одного из видов ячеистого бетона - газобетона. Проведенными исследованиями установлено, что при использовании мелкодисперсного заполнителя, образующегося в качестве отходов при резке кладочных камней из устричного известняка, получается безавтоклавный ячеистый бетон, физико-механические свойства которого

соответствуют нормативным требованиям. При использовании карбонатных отходов получают изделия из ячеистого бетона со средней плотностью 500 кг/м³ и прочностью до 2,5 МПа, что соответствует классу прочности D500 и B2. Использование карбонатных отходов и снижение расхода цемента обеспечивают снижение себестоимости ячеистого бетона на 30%.

Ключевые слова: портландцемент, газобетон, карбонатные отходы, плотность, удельная поверхность, прочность на сжатие.

Abstract: The increase in the volume of housing construction requires the development, creation and study of highly efficient thermal insulation materials. In modern construction, various types of aerated concrete are included in such construction materials. With the increase in the height of buildings, the reduction of the mass of the structure becomes more relevant. It is known that the thermal conductivity of a wall built of aerated concrete with a density of 1200 kg/m³ is 4 times higher than the thermal conductivity of a wall built of aerated concrete based on carbonate waste. Accordingly, when comparing walls with the same thermal insulation capacity, we see that the thickness of a wall built of limestone is 4 times greater than that of aerated concrete. Our research is aimed at obtaining autoclave-free aerated concrete based on carbonate waste, one of the types of aerated concrete - aerated concrete. The conducted studies have determined that by using the fine filler generated as waste during the cutting of masonry stones from oyster limestone, autoclave-free aerated concrete is obtained, the physical and mechanical properties of which comply with regulatory requirements. By using carbonate waste, aerated concrete products with an average density of 500 kg/m³ and a strength of up to 2.5 MPa are obtained, which corresponds to D500 and B2 in strength class. The use of carbonate waste and a decrease in cement consumption ensure a 30% reduction in the cost of aerated concrete.

Keywords: Portland cement, aerated concrete, carbonate waste, density, specific surface area, compressive strength.

Introduction. Currently, the main thermal insulation materials are mineral wool and polymer-based foam products. However, polymer-based foam products do not have sufficient durability. It is very difficult to obtain lightweight concrete with high thermal insulation capacity with the use of expanded clay filler with an average density of more than 800 kg/m³. Despite the effective use of expanded perlite, vermiculite, diatomite as fillers in cement systems, they are applied only in some regions. Therefore, non-autoclaved aerated concrete, like aerated concrete, occupies a special place among construction materials [1].

Internationally, the requirements for saving thermal energy are increasing sharply. The introduction of new requirements for increasing the thermal insulation properties of protective structures of buildings and structures of various functional purposes requires the constant expansion of the range of high-quality thermal insulation materials and the creation of new production technologies for highly efficient aerated concrete [2,3].

Aerated concrete has all the advantages that meet modern requirements for construction materials in terms of thermal insulation properties. However, most of the currently available technologies for its production require the use of quite expensive raw materials (Portland cement, lime, washed quartz sand, etc.), which negatively affects the cost and competitiveness of the

material. To solve this problem, it is relevant to develop new technological methods for the production of autoclaved aerated concrete using local raw materials and mineral industrial waste [4, 5]. This allows providing production with cheap and partially prepared sources of mineral raw materials, creating real opportunities for saving energy resources and capital investments. In this regard, it is relevant to conduct tests aimed at reducing cement consumption for the preparation of efficient types of porous concrete. In developed countries such as Denmark, Norway, Canada, the USA, and France, there is sufficient experience in the application of mineral fine fillers in cement. For example, in France, more than 30% of the volume of cement production is made up of cements with carbonate additives in the amount of 5-25%. In the USA, up to 50% of such additives are added to their composition during cement production [6].

A number of research studies have been devoted to the study of the effect of carbonate fine fillers on the properties of cement composites. In these studies, it was found that the mentioned filler causes compaction of the microstructure, increases the strength of the concrete matrix, and at the same time has a positive effect on the hardening process of the adhesive in the composition [6-8]. Finely dispersed limestone with a significant specific surface area, when used in an amount of 5-10%, plays the role of a plasticizer in the system, reducing the water requirement of the adhesive by 10-15%. When the amount of limestone is increased, the water requirement increases slightly, and the strength indicators at 28 days of hardening are 5-26% higher than those of ordinary cement, depending on the amount of the additive. The improvement of the plasticity of the cement paste with lower water consumption is explained by the fact that highly dispersed particles of limestone fill the voids between the cement grains that could be filled with water. The addition of chalk, which has a specific surface area significantly lower than that of limestone, significantly increases the water requirement of the cement paste, but in this case the strength properties of the chalk-filled adhesive are 15-30% higher than those of ordinary cement [9,10].

The aim of this study is to develop a non-autoclaved aerated concrete composition with physical and mechanical properties that meet regulatory requirements by using carbonate waste obtained during the grinding of limestone.

Materials and research methods. The studies used CEM I-52.5 Portland cement produced by HOLCIM Azerbaijan in accordance with the requirements of the AZS EN 197-1 standard, and carbonate waste generated during the production of sawdust in the Balykkulagli limestone quarry in the Turkan settlement of the Absheron region.

Mineralogical composition of Portland cement: C_3S –67%, C_2S –13%, C_3A –4.9%, C_4AF –11.9%.

Limestone shell rock is light brown, gray in color, sometimes with faint yellow spots. Its structure is porous. The main rock-forming mineral of the stone is calcite, its content is about 91%. The share of secondary minerals (oxides of iron, manganese, silicate minerals) is up to 9%. According to its mineral composition and structural and textural properties, the stone belongs to calcitic limestone.

To create pores, PAP-2 (GOST 5494-95) aluminum powder was used, and to accelerate the setting of cement, caustic soda and sodium sulfate were used.

The carbonate waste was first dried and ground in a ball mill to a specific surface area of 2500, 4500 and 6500 cm^2/g . The carbonate waste was used in an amount of 20%, 40% and 60% by mass of cement.

The components included in the aerated concrete mixture are weighed and mixed. Water with a temperature of 60°C is added to the resulting mixture and mixed for 1 minute. Then, a previously prepared aluminum suspension is added to the mixture and mixed for another 1 minute. The flowability of the mixture is determined using a Suttard viscometer. When the spreading diameter is 12.5-13 cm, the consistency of the mixture is considered normal. The aerated concrete mixture with a normal consistency is poured into molds measuring 10x10x10 cm. The mixture is filled to 2/3 of the mold. The mold is placed in a preheating chamber and after being kept at a temperature of 40-45°C for 3 hours, the part of the solution rising above the mold is cut off with a wire. Then the mold is opened and placed back in the chamber and kept at a temperature of 60-80°C for 6-8 hours. Then the samples are dried to a constant mass and physical and mechanical tests are performed.

Results and discussion. Nine compositions were prepared by varying the amount of carbonate waste and the specific surface area of carbonate waste in Portland cement and aerated concrete. To determine the effect of carbonate waste on aerated concrete, other components were kept constant (Table 1).

Table 1

Composition of aerated concrete based on carbonate waste with a specific surface area of 2500 cm²/g

No	Composition of aerated concrete, kg/m ³						Cylinder spreadability, cm
	Cement	Carbonate waste	Caustic soda	Na ₂ SO ₄	Aluminum powder	Water	
1	400	100	3	4,5	0.55	220	13
2	300	200	3	4,5	0.55	215	12.5
3	200	300	3	4,5	0.55	210	12.5

Other compositions prepared on the basis of carbonate waste with a specific surface area of 4500 cm²/g and 6500 cm²/g were also prepared according to table 1. In these compositions, only as the specific surface area of carbonate waste increases, the water requirement of the mixture increases by 5-7%.

It is known that the brand of aerated concrete is determined by its density. Therefore, the effect of the amount of carbonate waste on aerated concrete was studied. As can be seen, the density of aerated concrete decreases as the amount of carbonate waste increases (Fig. 1). When the amount of carbonate waste is 30%, the density is 465 kg/m³, and when it is 40%, it is 469 kg/m³. However, when the amount of carbonate waste is increased to 60%, the density drops to 454 kg/m³. This shows that when the amount of carbonate waste is up to 40%, the amount of fillers in the system is small. However, when the amount of carbonate waste is increased to 60%, the density of aerated concrete decreases significantly due to the equalization of the cement-filler balance in the system. When the amount of carbonate waste with a specific surface area of 4500 cm²/g is increased by 60%, the density of aerated concrete decreases from 506 kg/m³ to 430 kg/m³. When the specific surface area

of carbonate waste is increased to 6500 cm²/g, the density is 441 kg/m³. This shows that the surface area of carbonate waste can be increased to a certain extent. Otherwise, its effectiveness decreases.

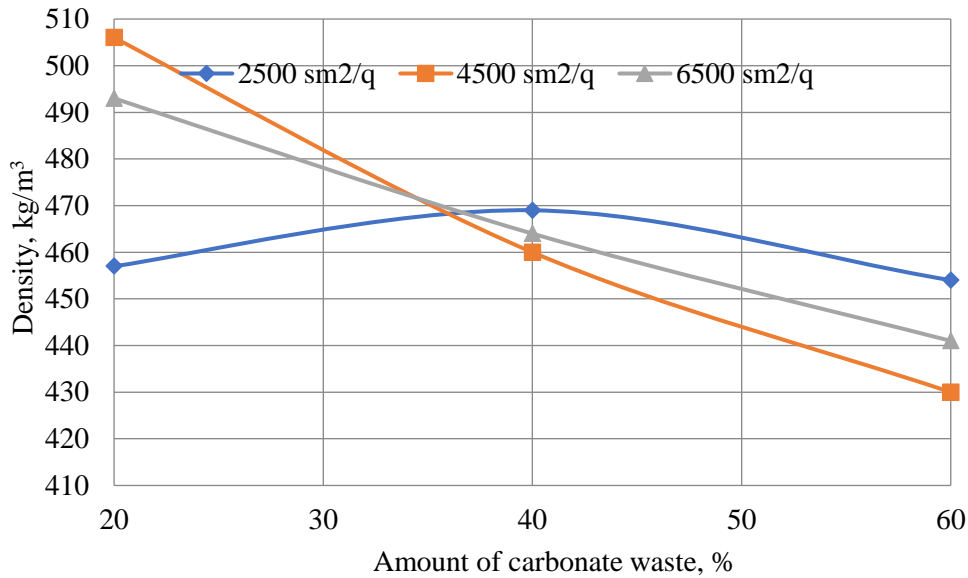


Fig. 1. Effect of carbonate waste on the density of aerated concrete

The dependence of the density of aerated concrete on the specific surface area of carbonate waste is given in Fig. 2.

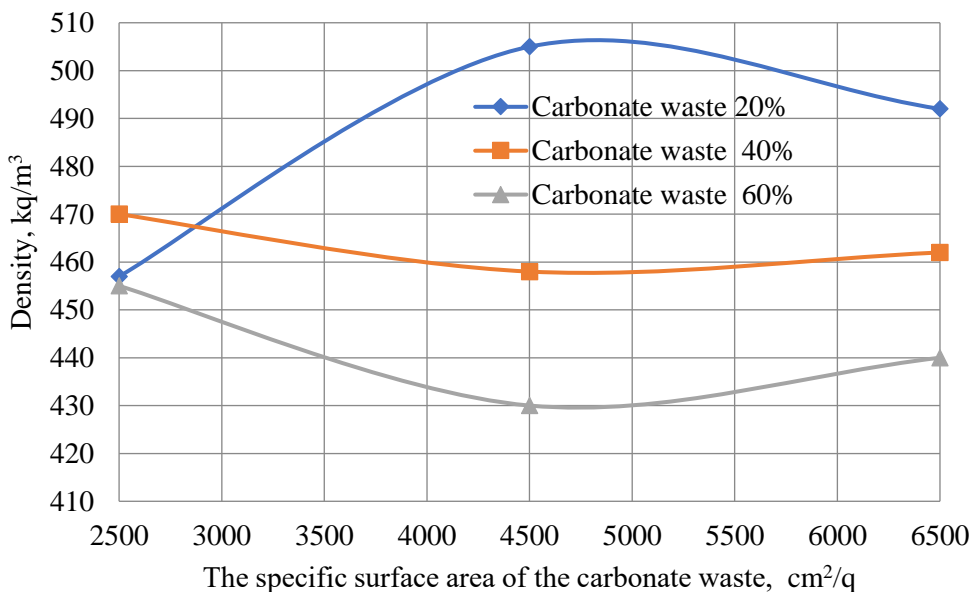


Fig. 2. Change in density of aerated concrete depending on the specific surface area of carbonate waste

As can be seen, when the amount of carbonate waste is 20%, when the specific surface area of the filler increases from 2500 cm²/g to 4500 cm²/g, the density increases to 505 kg/m³, but with a further

increase in the specific surface area, the density begins to decrease and becomes 492 kg/m^3 at $6500 \text{ cm}^2/\text{g}$. When the amount of carbonate rock is 40-60%, the density begins to decrease with an increase in the specific surface area. When the specific surface area is $4500 \text{ cm}^2/\text{g}$, the density of aerated concrete is the lowest.

Although the brand of aerated concrete is determined by its density, strength indicators also play an important role in the transportation and laying of products.

The change in the compressive strength of aerated concrete with an increase in the amount of carbonate waste is shown in Fig. 3.

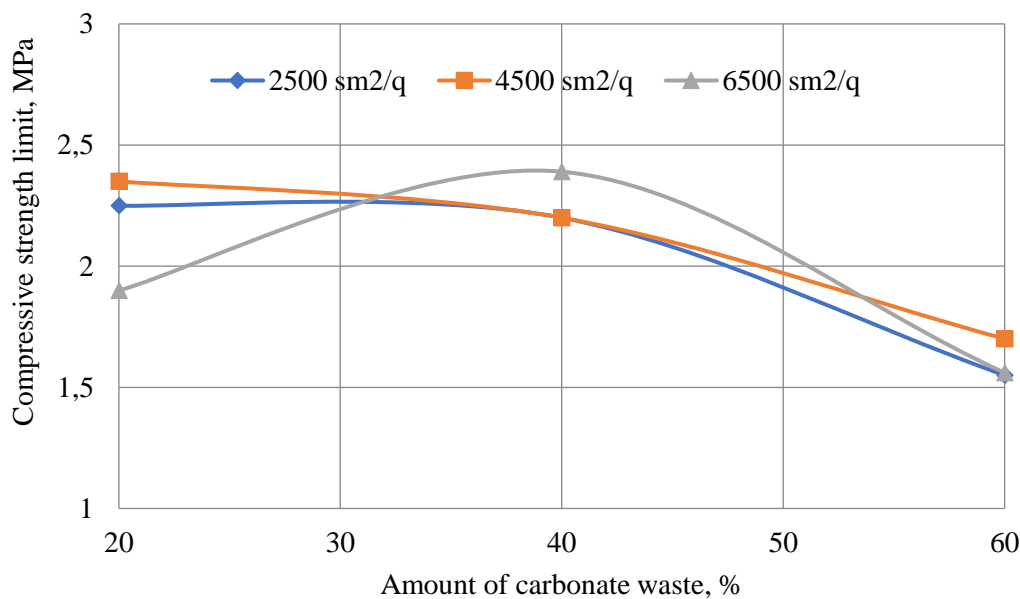


Fig. 3. Effect of carbonate waste on the strength of aerated concrete

Experimental results show that when the specific surface area of carbonate waste is $6500 \text{ cm}^2/\text{g}$, the strength of aerated concrete increases with an increase in the amount of filler from 20% to 40%. However, as the amount of filler increases from 40% to 60%, the strength decreases significantly. When the specific surface area of the fine filler is 4500 and $6500 \text{ cm}^2/\text{g}$, the strength of aerated concrete remains practically constant when the amount of carbonate waste is increased from 20% to 40%. Replacing a certain part of the cement with a carbonate fine filler does not reduce the strength of the composition, and in some cases even increases it, which allows reducing its cost without harming the quality of the material.

Fig. 4 shows the effect of the specific surface area of carbonate waste on the compressive strength of aerated concrete.

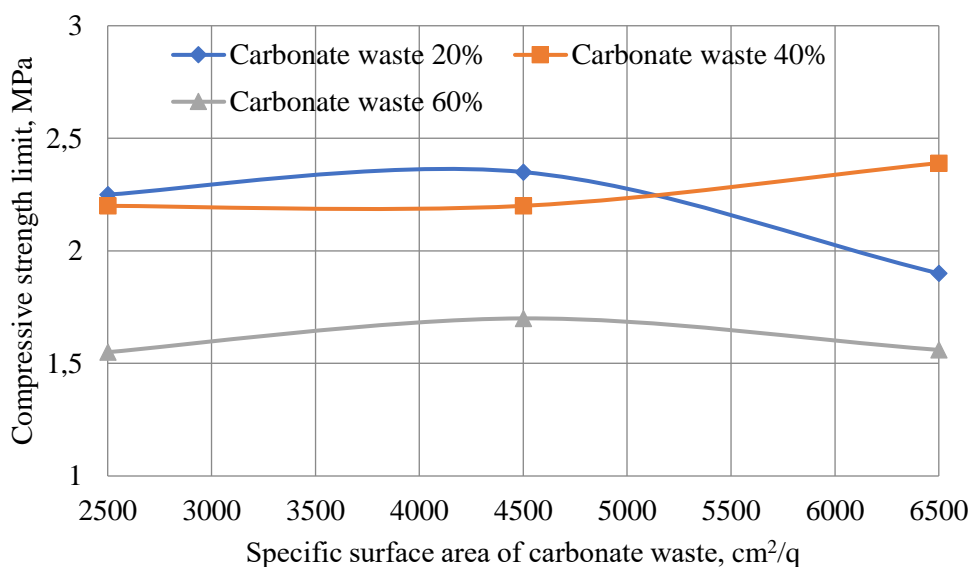


Fig. 4. Effect of carbonate waste with different specific surface area on the strength of aerated concrete

When the amount of carbonate waste is 60%, the strength limit increases until the specific surface area reaches 4500 cm²/g, but with a further increase in the specific surface area, the strength begins to decrease. This is due to the fact that as the fineness increases, the amount of particles per unit volume increases and there is a shortage of cement particles that can cover the carbonate particles. Therefore, the hydrate compounds that create adhesion between the carbonate particles cannot participate in the process. As can be seen from Fig. 4, when the amount of carbonate waste is 20-40%, aerated concrete samples give higher results. The specific surface area of the filler does not give a significant change in strength from 2500 cm²/g to 4500 cm²/g. However, as the specific surface increases, when the amount of carbonate waste is 40%, an increase in strength is observed. This indicates that optimal adhesion of cement particles and carbonate waste particles is ensured.

Conclusions. The increase in compressive strength of the cement composition with carbonate fine filler is determined by their ability to combine with the hydration products of Portland cement [11]. Our studies show that this property occurs when the fine filler is sufficiently dispersed, that is, its specific surface area is not less than 6500 cm²/g. When calcium carbonate is present in cement, a double compound of the CaCO₃·Ca(OH)₂ type is formed. Chemical interaction between Ca(OH)₂ and CaCO₃ is possible only during prolonged hardening of the cement. When there are favorable external conditions for the hardening of the material, water molecules gradually activate the surface layer of the carbonate and cause the diffusion of Ca²⁺, OH⁻, CO₃³⁻ ions in the structure of CaCO₃. As a result of this process, during prolonged hardening of the cement, an isomorphous bond is formed between Ca(OH)₂ and CaCO₃, which strengthens the structuring bond in the “cement - fine filler - water” system. Carbonate waste is not inert under normal conditions and also reacts with clinker minerals C₃A and C₄AF, forming complex compounds. These compounds consist of 3CaO·Al₂O₃·CaCO₃·11H₂O and 3CaO·Al₂O₃·MgCO₃·11H₂O, respectively. These compounds are stronger under normal conditions than the calcium-hydroaluminate compounds formed during the hydration of Portland cement. Their hexagonal crystals increase the strength of aluminate compounds. Therefore, since carbonates react with aluminate compounds of clinker and form strong

compounds, the strength of carbonated Portland cement is greater than that of the original Portland cement. As a result, an autoclave-free aerated concrete composition was developed with the use of carbonate fine filler, which is formed as waste during the crushing of limestone, the physical and mechanical properties of which comply with regulatory requirements. The combined presence of the indicated substances in the mixture with the proposed composition ensures the production of aerated concrete products with an average density of 500 kg/m^3 and a strength of up to 2.5 MPa, which corresponds to D500 in density and B2 in strength class. The use of crushed limestone waste and a decrease in cement consumption lead to a 30% reduction in the cost of aerated concrete compared to its analogues.

It is known that the thermal conductivity of a wall built with aerated limestone with a density of 1200 kg/m^3 is $\lambda=0.35 \text{ W/m}\cdot^{\circ}\text{C}$, while the thermal conductivity of a wall built on the basis of aerated concrete obtained from the waste of the same limestone is $\lambda=0.11 \text{ W/m}\cdot^{\circ}\text{C}$. In order to achieve the same thermal insulation capacity, the thickness of a wall built with aerated limestone should be 4 times thicker than that of a wall based on aerated concrete.

Thus, aerated concrete based on carbonate waste ensures a reduction in the mass of the structure, noise level, and energy and heat loss during the operation of buildings.

Literature

1. Ukhova, T.A. Prospects for the Development and Application of Cellular Concrete / T.A. Ukhova // Construction Materials. 2005. No. 1. p.18.
2. Davidyuk A.A., Fiskind E.S., Gusar O.A., Balakireva V.V. Advantages in the Production and Application of Cellular Concrete Blocks // Construction Materials. 2018. No. 12. pp. 41–43. DOI: <https://doi.org/10.31659/0585-430X-2018-766-12-41-43>
3. Serova R.F., Kasumov A.Sh., Velichko E.G. Problems of Production and Application of Cellular Concrete // Fundamental Research. 2016. No. 7-2. pp. 267-271
4. Dyikanbaeva N.A. Non-aqueous aerated concrete from natural and man-made raw materials of Kyrgyzstan // Bulletin of KRSU. 2017. Volume 17. No. 1, pp. 123-126
5. Kasymova M.T. Properties of cellular concrete from local raw materials with modifying additives / M.T. Kasymova, N.A. Dyikanbaeva // Bulletin of KRSU. 2015. No. 3. pp. 169–172.
6. Proshin, A.P. Foam concrete (composition, properties, application) / A.P. Proshin [and others]. Penza: PGUAS, 2003. 162 p.
7. Stelmakh S.A. Influence of complex additive on physical and mechanical properties of non-autoclaved aerated concrete / E.M. Shcherban, E.O. Lotoshnikova, A.V. Yanovskaya, N.A. Dotsenko // Bulletin of BSTU named after V.G. Shukhov 2017, No. 9, pp. 15-18
8. Yavruyan H.S., Influence of some formulation and technological factors on the properties of non-autoclaved aerated concrete / M.G. Kholodnyak, A.I. Shuysky, S.A. Stelmakh, E.M. Shcherban // Engineering Bulletin of the Don. 2015. No. 4 [Electronic resource]. System requirements: Adobe Acrobat Reader. URL: ivdon.ru/ru/magazine/archive/n4y2015/3431
9. Yundin, A.N. Cellular composites with a carbonate-containing component in a single-stage preparation of foam concrete mixture. / A. N. Yundin, G. A. Tkachenko, E. V. Izmalkova // News of universities. Construction. 2000. No. 12. pp. 40 - 44.
10. Kopanitsa, N. O. Finely dispersed additives for filled binders based on cement / N. O. Kopanitsa, L. A. Anikanova, M. S. Makarevich // Construction materials. 2002. No. 9. pp. 2-3
11. Gvalov A.A., Abbasova S.I. Technology of composite materials. Baku. 2018. 196 p.

12. Hasanov B.B., Allambergenov A.J. «Integrated physico-chemicals study of the unfluence of a microfiller on the formation on the structure and properties of lightweight concrete». Journal of NORTHEASTERN UNIVERSITY. SCOPUS. Volume 25, Issue 04, December, 2022.
13. Hasanov B.B. «O'zbekiston sharoitida ko'pikbeton bloklarning uzoqqa chidamlilik xossalarini oshirish». Research and Education. Scientific Journal Impact Factor 2022: Vol. 1, Issue 8, 26-31 pages, November, 2022.
14. Хасанов Б.Б. “Прочность, плотность, морозостойкость и долговечность газобетонных блоков” Research and Education. Scientific Journal Impact Factor 2022: Vol. 1, Issue 7, 68-73 pages, October, 2022.
15. Hasanov B.B. «Research of thermal properties of small blocks made of lightweight concrete on a porous filler from coal mining waste». Central Asian Journal of Stem. YTIT. 1/2021, 59-63 pages. (Toshkent sh. YoDJU texnika instituti).

