ENGINEER

international scientific journal

ISSUE 1, 2025 Vol. 3
E-ISSN
3030-3893
ISSN
3060-5172

A bridge between science and innovation

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

ENGINEER

A bridge between science and innovation

E-ISSN: 3030-3893

ISSN: 3060-5172

VOLUME 3, ISSUE 1

MARCH, 2025

engineer.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

ENGINEER

INTERNATIONAL SCIENTIFIC JOURNAL

VOLUME 3, ISSUE 1 MARCH, 2025

Founder of the international scientific journal “Engineer” – Tashkent State Transport University, 100167, Republic of Uzbekistan, Tashkent, Temiryo‘lchilar str., 1, office: 465, e-mail: publication@tstu.uz.

The “Engineer” publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

The journal is published 4 times a year and contains publications in the following main areas:

- Engineering;
- General Engineering;
- Aerospace Engineering;
- Automotive Engineering;
- Civil and Structural Engineering;
- Computational Mechanics;
- Control and Systems Engineering;
- Electrical and Electronic Engineering;
- Industrial and Manufacturing Engineering;
- Mechanical Engineering;
- Mechanics of Materials;
- Safety, Risk, Reliability and Quality;
- Media Technology;
- Building and Construction;
- Architecture.

Tashkent State Transport University had the opportunity to publish the international scientific journal “Engineer” based on the **Certificate No. 1183** of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. **E-ISSN: 3030-3893, ISSN: 3060-5172.** Articles in the journal are published in English language.

Production of aerated concrete blocks using energy-efficient technology

B.G. Kodirov[1][a], S.S. Shaumarov[1][b], S.I. Kandakhorov[1][c]
[1]Tashkent state transport university, Tashkent, Uzbekistan

Abstract: This article studies the problems of producing aerated concrete blocks using energy-saving technology and ways to overcome them. Aerated concrete products are distinguished by their lightness, low thermal conductivity compared to traditional concrete, and the ability to effectively recycle industrial waste. The article analyzes the influence of the structure of pores in aerated concrete, their diameter and uniformity, on thermal conductivity and strength properties. The results of the study show that aerated concrete produced using industrial waste contains uniformly distributed closed pores, which reduce the thermal conductivity of aerated concrete by 2–4.5% and increase its strength by 7–12%. At the same time, the use of cold water without adding hot water to the mixture, and the technology of covering the mold and sending it to evaporation chambers are recommended. These methods are energy-efficient, simplify the technological process, and increase the quality and environmental safety of the product. The research also shows the possibility of improving the physical and mechanical properties of two- and three-layer aerated concrete blocks with a dense surface layer. They have high potential in terms of recycling industrial waste, heat conservation, technological simplicity, and environmental sustainability.

Keywords: concrete technology, concrete mix, density, porosity, surface layer

1. Introduction

Against the background of growing requirements for energy saving and environmental friendliness of building materials, the production of aerated concrete blocks using energy-efficient technologies is becoming especially relevant. Aerated concrete is a type of cellular concrete with low density, high thermal insulation and sufficient strength, which makes it indispensable in low-rise and energy-efficient construction.

Modern technologies for the production of aerated concrete are aimed not only at improving the physical and mechanical characteristics of products, but also at reducing energy costs at all stages: from the preparation of the raw mix to autoclave processing. The introduction of automated component dosing systems, optimization of autoclaving modes, reuse of process heat and water, the use of alternative binders - all this can significantly reduce energy consumption and reduce the cost of products without loss of quality.

In addition, special attention is paid to the use of secondary resources, such as fly ash, microsilica or construction waste, which corresponds to the concept of sustainable development and a closed production cycle.The technology of production of aerated concrete products is related to the composition of bodies in the concrete mix: the porosity that forms the concrete structure, its formation methods, the strength of aerated concrete and many other specific properties. As a result of the interaction of one of the main components of the concrete mix with the gas-forming (usually aluminum powder) and calcium hydrate oxide, hydrogen is released, which is poorly soluble in water and forms gaseous pores in the concrete mix.

As the volume of spherical pores (cells) of gas increases, the volume of concrete also swells (expands) by 1.2-1.8 times. The formation of gas and the expansion of the concrete mix may not proceed smoothly. This depends on the following factors: rheological properties of the mixture, the temperature of the raw material and the environment, the alkalinity and exothermicity of the binder, the displacement of the mold in the shop, etc. [1].

Instability in the swelling of the mixture leads to changes in the density of aerated concrete. As a result, aerated concrete has the following performance characteristics than other types of concrete: average density, thermal conductivity, strength, etc. [2, 3].

If the heavy concrete has almost the same density (average 2400 kg/m3) regardless of the strength class, then the value of the density of aerated concrete varies from 300 to 1200 kg/m3.

Light concrete mix differs from heavy concrete mix by greater flexibility.

Due to the high consistency of the aerated concrete mix, it consists of the process of preparation and molding of aerated concrete products, ie casting. The aerated concrete mixture poured into the mold expands, taking the form of a mold. The volume of concrete mixture raised from the top level of the mold reaches 10-15%. The hoist should be cut and removed flat from the surface of the mold. Returning the cut lift to the concrete mixing device is cost-effective in fully mechanized plants. Returning the cut lift to the concrete mixing device requires a large amount of manual labor in small enterprises, and it is often discarded [4, 5].

2. Research methodology

One of the advantages of aerated concrete products is: it has the lowest average density among all known types of concrete (300-1200 kg/m3); maximum thermal conductivity resistance (0.08-0.29 W/m·°C); maximum fire and frost resistance; has the maximum potential for industrial waste utilization.

One of the specific properties of aerated concrete products, which differs from other concretes, is: preparation of concrete mix without coarse aggregate; cast consistency

[a] https://orcid.org/0009-0006-8828-1645
[b] https://orcid.org/0000-0001-8935-7513
[c] https://orcid.org/0000-0002-3689-8794

(melting of the mixture on the Suttard cylinder 12-35 cm); addition of hot water at a temperature of 50-70 ˚C to the mixture (optimal for gas formation and increase in the volume of the mixture).

The introduction of hot water at excess temperature into the concrete mix has a negative impact on the physicochemical properties of aerated concrete, such as increased demand for water, decreased strength, premature formation of sand.

When molding products, the aerated concrete mix is not completely filled into the formwork because the aerated concrete mix expands to fill the remaining volume of the formwork cavity. In order to properly form the concrete structure and optimize the gas formation process, in practice it can be obtained by preparation in the form of a low-consistency compound (11-13 sm) and by vibration. After the expansion process of the mixture is completed and after cutting, exposure to the mold (shaking, strokes, etc.) is not recommended as the mixture will shrink.

Such technological operations are carried out only with aerated concrete mix. Other types of heavy concrete mixes are laid on the mold balance and brought in using vibro compaction. The volume of these vibro-compacted concrete mixes does not change. Another type of lightweight concrete mix is foam concrete, which is poured in the ready state of foaming over the entire height of the mold, then the foam concrete mix does not expand in the mold and can sometimes sink to 1-3%.

As for concrete production technologies, there is a technology for adding the mixture to the formwork from above in the open position for porous concrete.

Disadvantages of traditional aerated concrete technology include:

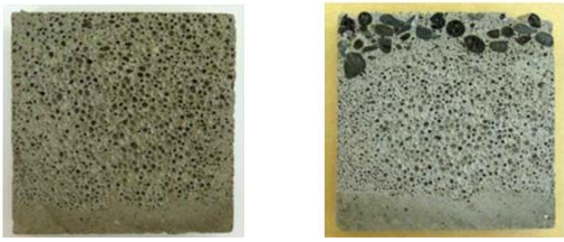
• introduction of hot water into the concrete mix;

• energy consumption for heating water to 50-70 °C;

• the need to store the molded concrete mixture in a special heat and humidity chamber at a temperature of 40 ± 5 °C for 5-6 hours;

When pouring aerated concrete into the formwork, compaction of the upper part of the formwork based on the technology of "light compaction roller" is not considered efficient enough and therefore requires special equipment;

One of the unique properties of building materials made of aerated concrete is the open porosity of concrete and their strength. The open porosity of the surface of the products leads to the subsequent deterioration of water absorption, capillary pods, many important operational properties of aerated concrete. Therefore, it is necessary to protect the surfaces of external walls made of porous concrete from mechanical and external climatic influences (covering the surface with plaster). Thus, reducing the porosity and increasing the strength of the surface of the layers allows to overcome many shortcomings of aerated concrete. In order to increase the rigidity and strength of the outer layers of aerated concrete products, it is proposed to cover two- and three-layer aerated concrete blocks with a compacted surface layer of a denser material. In this case, the cement-sand mixture in the ratio "Cement: sand = 1: 3" and the top surface can be covered with materials consisting of a light porous filler. The thickness of the compacted layers is 1 - 2 cm. The middle layer consists of an aerated concrete mix with a density of 400 - 500 kg/m3. In this design, the physical and mechanical properties of composite concrete are improved, and the surface of aerated concrete products differs from ordinary concrete in the strength of layered aerated concrete with a density of 600-700 kg/m3.(Fig. 1).



a b

Figure 1. Aerated concrete samples:

a - two-layer aerated concrete consisting of a dense cement-sand mixture; b - three-layer dense mix and lightweight concrete aerated concrete consisting of a surface layer

In order to improve the production of aerated concrete blocks based on energy-saving technologies, industrial waste from the "Foundry Mechanical Plant" of JSC "Uzbekistan Railways" was used, and the structure of aerated concrete samples was investigated (Fig. 2). In this case, when forming porous concrete block samples, aerated concrete consists of structural walls containing closed and open macro-micropores and microcapillaries. Usually, the pores should have a closed straight spherical shape and be evenly distributed throughout the entire volume of concrete.

The composition of the aerated concrete structure made from industrial waste sand and steel smelting slag was analyzed in the laboratory after 28 days. An overview of the samples is presented in Fig. 2.

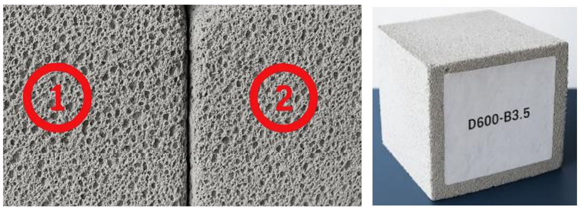


Figure 2. External view of D600 aerated concrete samples

Here, along with micropores, large-diameter macropores are depicted. The pores of aerated concrete based on industrial waste quartz sand have a macrostructure that is close to each other. In this case, the pores of the sample tend to be uniform and the number of interconnected pores is small. This, in turn, leads to an increase in the thermal insulation properties and strength properties of aerated concrete.

The proposed aerated concrete cellular structure has a regular spherical geometric shape, and the non-autoclaved aerated concrete based on steel smelting slag consists of pores of various sizes of 1.2-3.1 mm, which are evenly distributed. The recommended composite aerated concrete based on industrial waste quartz sand and slag has a maximum pore diameter of 1.5 mm and pores of 1 mm or less.

The study of the structural composition of autoclaved aerated concrete was carried out according to the methodology "Binders and concretes from artificial and mineral raw materials" [5].

3. Results and Discussion

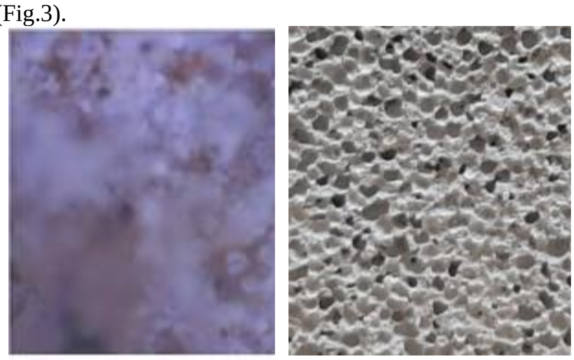
The conducted studies show that the dimensions of micro and macro pores determine the physical and mechanical properties of aerated concrete (Table 1).

Table 1

Pores of aerated concrete

Thermal conductivity, Vt/m·°C	Pore sizes, mm	Thickness of the pore walls, мм	Average density, kg/m³	Strength, MPa	Hollowness, %
0,143	p1=2,220 p2=1,480 p3=3,171	2,020	663	1,67	63
0,141	p1=2,103 p2=1,602 p3=2,434	2,187	665	1,668	61,6
0,152	p1=1,808 p2=1,205 p3=1,582	1,990	660	1,62	63,5

The results of the analysis of the aerated concrete structure show that the micro- and macrostructure of aerated concrete produced using industrial waste quartz sand differs from concrete without the addition of waste in that the pores are relatively uniform and have regular spherical shapes (Fig.3).



a) b)

Figure 3. Micro and macrostructures of aerated concrete:

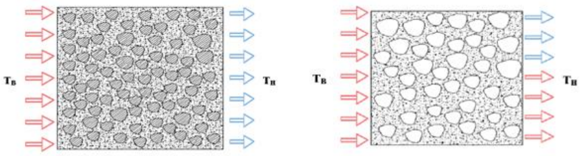
a – microstructure (10^{-5} μm);

b – macrostructure (1.48-3.17 mm)

Aerated concrete samples produced using industrial waste sand show better results in terms of thermal conductivity than aerated concrete samples based on waste slag. This is due to the presence of slag in its composition, which has a low thermal conductivity. This is due to the evenly distributed porous structure, which improves the physical and mechanical properties of aerated concrete.

To study the structure of aerated concrete, it is important to study its micro-macrostructure. Analysis of the microstructure allows us to study its porosity or average density. Based on these analyses, it is shown that the physical and mechanical properties and water absorption depend on the structure of aerated concrete.

Figure 4 shows the comparative characteristics of pores and thermal conductivity of aerated concrete in the proposed and production organization.



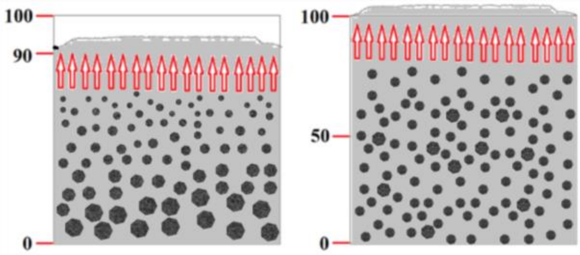
a) b)

Figure 4. Scheme of arrangement of pores of aerated concrete blocks:

a) proposed aerated concrete; b) aerated concrete of the production organization

This figure shows that aerated concrete contains a large number of pores and the location of these pores is different, the thermal conductivity will be different. Also, the smaller the size of the filler materials, the higher the aerated concrete mixture will be, and the pores will be the same. At the same time, the thermal conductivity will decrease by 2-4.5% compared to a structure with different pores.

The sand fractions in the composition of aerated concrete have a significant impact on its lifting height (Fig. 5).



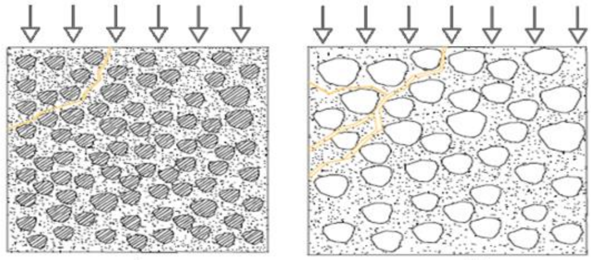
a) b)

Figure 5. The height of the mixture:

a - aerated concrete made of sand with dimensions of 0.315-0.63; b - aerated concrete made of sand with dimensions of 0.15-0.315

The lifting height varies depending on the type and fraction size of the sand in the aerated concrete mixture. Also, the smaller the fractions of the sand in the aerated concrete mixture, the easier it is to lift. The larger the fraction, the more difficult it is to lift and the more aluminum powder is required.

The greater the amount of fillers in the composition of aerated concrete, the less uniform the distribution of concrete particles and the more likely microcracks to appear in aerated concrete structures (Fig. 6).



a) b)

Figure 6. Defects of aerated concrete blocks that occur during compression:

a) offered aerated concrete; b) aerated concrete in production

As can be seen from Figures 5 and 6 above, aerated concrete pore spaces made from sand with fraction sizes of 0.15–0.315 have significantly better strength, thermal conductivity, and porosity than aerated concrete made from sand with a fraction size of 0.315–0.63, due to their tendency to be uniform.

The porous structure of the samples was tested using a Thermo Scientific Pascal porosimeter in the research laboratory of the Department of “Construction of Buildings and Industrial Facilities” of Tashkent State Transport University. According to the results of the study, the samples with the best characteristics were identified. The results of this experimental study are presented in Figures 7 and 8.

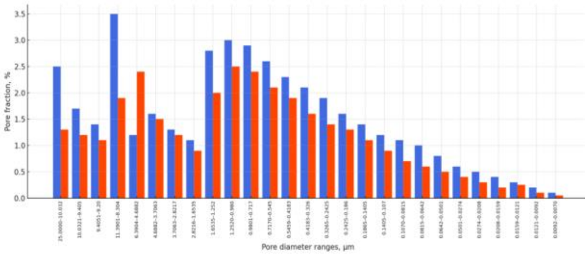


Figure 7. Diagram of percentage pores of non-autoclaved aerated concrete blocks made using steel smelting slag and waste quartz sand:
(1-industrial waste, 2-steel smelting slag)

The graph of pore diameters and their corresponding percentage distribution, constructed based on the experimental results, gives an idea of how the pore volumes are distributed in two different samples. Each curve has a unique shape, and the peak (maximum point) in it reflects the most common (i.e., dominant) pore diameters in the sample. For a deeper analysis of these graphs, they are evaluated based on mathematical distribution models. In studies of porous materials, modeling of pore diameter data using statistical distribution functions is widely used. In particular, the log-normal distribution model is considered acceptable for materials such as cement-based composites and aerated concrete. In this model, the logarithm of the pore diameter is considered to be normally distributed. We use a single-peak Gaussian (normal) distribution model as a simple and understandable approach. This model represents the average diameter of pores in the material (μ) and the standard deviation (σ) of the diameter distribution. Here: μ - is the peak of the curve (i.e., the diameter at which the pore fraction is highest), σ - is the extent to which the pore diameters are spread out.

The probability density function of the normal distribution is written as:

$$f(d) = \frac{1}{\sigma\sqrt{2\pi}} \cdot \exp(-\frac{(d-\mu)^2}{2\sigma^2}) \qquad (1)$$

where:

d - is the pore diameter; μ - is the mean diameter; σ - is the standard deviation;

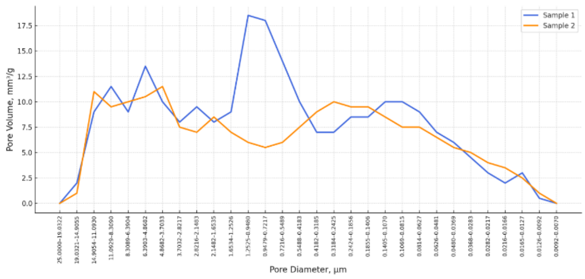


Figure 8. Diagram of pores versus volume of non-autoclaved aerated concrete blocks made using steel smelting slag and waste quartz sand:
(1- waste quartz sand and steel smelting slag, 2 - steel smelting slag)

The results of the experiment show that 0.1-0.3 mm pores make up 10-12% of the content obtained from production, while this indicator made up 20-24% in the samples with added industrial waste. In this case, the increase in the amount of micropores when comparing the samples is achieved due to the fact that the surfactants in the steel melting slag facilitate the hydration reaction in the mixture.

Thus, studies have shown that the thermal conductivity of aerated concrete is affected by the given concrete structure and the thermal conductivity coefficient of the raw materials used. It was possible to obtain non-autoclaved aerated concrete from natural and man-made raw materials of Uzbekistan, the thermal conductivity of which meets the requirements of GOST 10180-2012 for non-autoclaved aerated concrete and does not exceed 0.14-0.18 W/m·°C.

As a result of experimental studies, it has been scientifically proven that by achieving an even distribution of pores throughout the volume of aerated concrete, its thermal conductivity is improved by 2-4.5%, and its strength indicators by 7-12%. Taking this into account, in the next section we will conduct scientific research on the impact of water absorption and frost resistance on the factors affecting the operation of aerated concrete.

The development of porous structure and gaseous (non-naturally closed) pores with closed-type spherical pores in an open mold is characterized by the impossibility of obtaining freely compacted inter-porous barriers.

As a result of the research, the following is proposed to address the above shortcomings:

• adding unheated water to the aerated concrete mix;

• during the preparation of aerated concrete products, cover the concrete mix with a sturdy lid in the form of a cover or pallet;

• sending the aerated concrete mixture poured into the mold to the evaporation chamber preheated to 40-45 ° C;

• Immediately send the mold to the evaporator chamber, without first holding the process of hot-wet processing of the product.

Research and analysis of the literature confirm that these proposals are expedient and that their implementation is effective. Adding unheated water to the aerated concrete mix significantly simplifies the technology, in addition to saving the electricity typically used to heat the water, preventing the risk of premature expansion of the mix. However, it is important to perform this process in closed molds.

This paper presents the possibility of obtaining the bottom layer of the formwork mixture from the cement-sand mixture in the production of two-layer concrete, the upper part of the aerated concrete mixture by spraying the cement-sand dry mix and then laying the formwork with a lid. In this case, it is advisable to sprinkle the outer surface of the aerated concrete mixture with a thin layer of cement only to fill the surface pores.

In the future, it is planned to conduct extensive research in the field of production of aerated concrete products on the basis of the above technology, the study of the effect of the dense outer layer on their mechanical and thermal properties.

4. Conclusion

The production of aerated concrete blocks based on energy-saving technologies allows saving resources in the modern construction industry, reducing environmental impact, and creating high-quality products. Experiments conducted during this study have shown that the optimal diameter and uniform distribution of pores in the aerated concrete structure not only significantly reduces the thermal conductivity of the material, but also improves its main technical indicators, such as strength and service life. Aerated concrete blocks, made on the basis of inexpensive and environmentally safe raw materials obtained by processing industrial waste, not only meet the demand for energy-saving building materials, but also serve environmental protection. Such technological approaches as the simplification of heat treatment stages, the avoidance of hot water, and the direct sending of molds to the evaporation chamber are a practical manifestation of the modern production approach. The final conclusion is that the production of aerated concrete products through energy-efficient methods is not only a technological innovation, but also a strategic solution that ensures environmental and economic sustainability. This approach creates a solid scientific and practical foundation for the sustainable development of the construction industry in the future.

References

[1] Lotov A. V., Mitina N. A. Features of technological processes for the production of aerated concrete // Building materials. 2003. No. 1. S. 7-9.

[2] Production of cellular concrete products: the theory of practice / N. P. Sazhnev et al. Minsk: Strinko, 1999. 284 p.

[3] Autoclaved concretes / S. A. Mironov et al. M.: Stroyizdat, 1998. 280 p.

[4] Electrometallurgy of steel and ferroalloys / Povolotsky D.Ya., Roshchin V.E., Ryss M.A., Stroganov A.I., Yartsev M.A. Textbook for universities. Izd. 2-th, reworked. And supplement. M.: Metallurgy. 1984. - 568 c.

[5] Kasymova M.T. Temperature factor in the production technology of fiber-reinforced concrete [Text] / M.T. Kasymova, N.A. Dyikanbaeva // Proceedings of the international scientific and practical conference "Regional aspects of the development of science and education in the field of architecture, construction, land management and cadastres at the beginning of the III millennium. Scientific readings dedicated to the memory of Professor A.P. Sapozhnikov", Komsomolsk-on-Amur: FGBOU HPE "KnAGTU". 2014.-P. 280-285.

[6] Gorlov Yu.P. Refractory and heat-insulating materials [Text] / Yu.P. Gorlov, I.F. Eremin, B.U. Sedunov. - M.: Stroyizdat, 2006.-192 p.

[7] Adilkhodjaev, A., Makhamataliev, I., Tsoy, V., Shaumarov, S., Ruzmetov, F. Features of Forming the structure of cement concrete on second crushed stone from concrete scrap. International Journal of Advanced Science and Technology, 2020, 29(5), стр. 1901–1906

[8] Shaumarov, S., Kandakhorov, S., Umarov, K. Development of the Optimal Composition of Aerated Concrete Materials on the Basis of Industrial Waste. AIP Conference Proceedings, 2022, 2432, 030087

[9] Adilkhodjaev, A., Tsoy, V., Khodzhaev, S., Shaumarov, S., Umarov, K. Research of the influence of silicon-organic hydrophobizer on the basic properties of cement stone and mortar. International Journal of Advanced Science and Technology, 2020, 29(5), стр. 1918–1921.

Information about the author

Kadirov Bahodir Gayratjon ugli	Tashkent State Transport University "Building and industry facilities Construction Department doctoral student E-mail: bahodirqodirov55@gmail.com Tel.: + 998712990046 https://orcid.org/0009-0006-8828-1645
Shaumarov Said Sanatovich	Tashkent State Transport University "Building and industry facilities Construction Department professor (DSc), E-mail: shaumarovss@mail.ru Tel.: + 998712990026 https://orcid.org/0000-0001-8935-7513
Kandakhorov Sanjar Ishratovich	Tashkent State Transport University "Building and industry facilities Construction Department associate professor (PhD), E-mail: sanjar.kandakharov@mail.ru Tel.: + 998500717191 https://orcid.org/0000-0002-3689-8794

CONTEXT / MUNDARIJA