

The effect of antifreeze reagent on seasonal frozen soils

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ABSTRACT

The design, construction, and maintenance of pile foundations are dependent on special weather conditions in Northern and Central part of Kazakhstan. The winter months in these areas are very long which starts from November to March and the air temperature usually reaches – 40-50°C. These circumstances lead to the seasonal freezing ground, special physical behavior of soil, physical properties of construction materials. The main problem of pile driving in winter is frozen ground which is difficult to excavate and driving. Moreover, the Static Load Tests for estimating the bearing capacity of pile foundations do not show accurate records in frozen soil. To solve the problems mentioned above, a special antifreeze composition has been developed and established its protective effect against soil freezing in winter. The implementation of the proposed method leads to a high productivity of driving reinforced concrete piles without the risk of their destruction. This eliminates the need for additional drilling works and more powerful and expensive rock drills, if the soil is protected from freezing. According to a special formula, the optimal mass of antifreeze is calculated, which allows protecting the soil without harming not only the soil, but also the structure of the concrete pile and the environment. During the static load test, piles driven into soil that had been covered with antifreeze has showed more accurate bearing capacity data. Scientific and experimental studies have established that antifreeze reduces the compressibility of frozen soil.

Keywords: Pile foundations, Weather conditions, Thawing effect, Risk of destruction, Temperature influence.

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1. Introduction

Choosing a suitable foundation depth and protection of piles from effects of frost is very important in areas of seasonal frost, especially where there is frost-susceptible soil. According to the study [1] driving pile on frozen soil arise harmful frost actions. The lenses of ice produce forces which lead to the displacement of all parts of the foundation. Authors of the study claim that the soil should be prevented from freezing or replaced with a frost-stable material during the pile installation and designing foundation in winter [1-4]. The research conducted by H. Vazari and Y. Han [1] has noted the significant influence of a frozen layer on the dynamic response of piles even if the frozen layer is 0.5 m. Also, the results of an article [5] have proved the impact of seasonal frozen soils on the dynamic behavior of bridges supported by pile foundations in cold regions. Authors have found the interrelation between the effects of salinity and temperature which affects the unfrozen underground water that influences on the behavior of soils. The ice crystals are formed from salt ions which

during the temperature decrease they influence unfrozen soils [6] The temperature of the soil has a significant effect on the strength and behavior of piles. The studies about the variation of adfreeze bond strength on frozen materials in different temperature have been shown in studies of J. Weaver and N. Morgenstern [7], and frozen materials in saline permafrost in research of Y. Velli and A. Karpunia [8]. Moreover, author of the research [9] claims that frozen ground deforms under prolonged load and shows his lateral pile analysis on frozen soil. The results of study also have presented some notable differences between warm and frozen soils in displacement, effective stiffness, and maximum moment, shear demand during the experiment on bridge columns installed in warm and seasonally frozen soils [8; 10; 11].

Authors of a research [12] have demonstrated information about the diversity and variety of frozen soil and presented approaches on how to deal with frozen soils in designing structure by summarizing the most recent studies. The purpose of the experiment is determination the effect of antifreeze reagent on soils during the pile driving. The piles were driven in three different soils where the first pile was driven at the frozen ground, the second pile was driven into the normal ground, and the third pile was installed into the soil where antifreeze reagent was applied. The subject of this study is the role of antifreeze reagent in driving piles and testing the bearing capacity of piles in winter.

2. Materials and methods

In the geotechnical laboratory of KGS-Astana, the mechanical properties of soil were determined. The territory of the site is located in Nur-Sultan city. The geological structure at the survey site includes alluvial deposits of the Middle-Upper Quaternary age aQII-III, represented by clayey soils (loam, sandy loam, clay), sands of various sizes (fine, medium, large) and gravelly sands, as well as deposits of the Paleogene system Oligocene Pg33, represented by clayey soils. All of the above deposits are covered with a soil-vegetation layer. Mineralization of groundwater is $1975 \div 3765$ mg / l, which characterizes them as saline. The chemical composition of the water is sulfate-chloride calcium-magnesium and calcium-magnesium-sodium, the total hardness is $19.75 \div 46.5$ mol / dm³, the waters are very hard (Figure 1).



Figure 1. Preparation of materials for scientific and experimental work: cutting the soil for testing

According to the total content of easily and moderately soluble salts, the soils that make up the survey area are non-saline. Based on the field description of the soils and the results of laboratory tests, the soils were divided into engineering-geological elements (IGE) in the stratigraphic sequence of their occurrence. The following are the elements of the soil:

- IGE-1. Topsoil – tQIV;
- IGE-2. Loam – aQII-III;

- IGE-3. Sandy loam – aQII-III;
- IGE-4. Clay – aQII-III;
- IGE-5. Fine sand – aQII-III;
- IGE-6. Sand of medium size – aQII-III;
- IGE-7. Coarse sand – aQII-III;
- IGE-8. Gravelly sand – aQII-III;
- IGE-9. Clay – Pg33.

Laboratory driving piles was conducted in three different boxes. The boxes were made from wood with dimensions of 150 (length) x 70mm (width) x 250 mm (height). The first box was filled up with soil and the second box was filled up with soil with antifreeze reagent on surface. These two boxes were put into the freezer for seven days where the temperature was -30°C . The third box was filled up with soil and kept for seven days at room temperature. The model piles were made from plastic and printed by 3D Printer. The size of piles was 10x10 mm (thickness) x 150 mm (length). The mass of each pile is 12 mg. The density of the plastic is 1.38 g/cm^3 . Piles were modeled from the piles with sizes 40x40 (thickness) and 600 m (length) in a ratio 1:40 (Figure 2) [5].



Figure 2. The model piles made of plastic

Method of calculation of antifreeze reagent consumption was as follows. Antifreeze reagents in Kazakhstan are usually used on roads in dealing with winter slipperiness and they are applied according to the norms of established method. It is important to determine how much antifreeze reagent should be used in order to prevent soil freezing in winter time as it affects not only soil but also environment, structure of the pile, and foundation. The calculation of the chemical reagents consumption on roads to thaw the snow and ice was considered in the work of Doctor of Technical Sciences. A. Kiyalbayev [13] and a PhD A. Sarsembayeva [14]. Authors note that the mass of the reagents can be determined by the density and thickness of the snow-ice, and melting capacity of the reagent. Based on that formula, it has been calculated the mass of antifreeze reagent for the sandy loam layer as the reagent is applied on top of the soil. In order to plot a Gibbs diagram at the university's laboratory, it has been identified the different concentration of antifreeze reagent in different temperature. The mixture of water and reagent in ratio 1:30 was in a liquid state until the -50°C , below that temperature the water in soil has started to crystallize and formed ice and salt formation. The most expressive characteristic of the salt-water system is given in Gibbs diagram below (Figure 3).

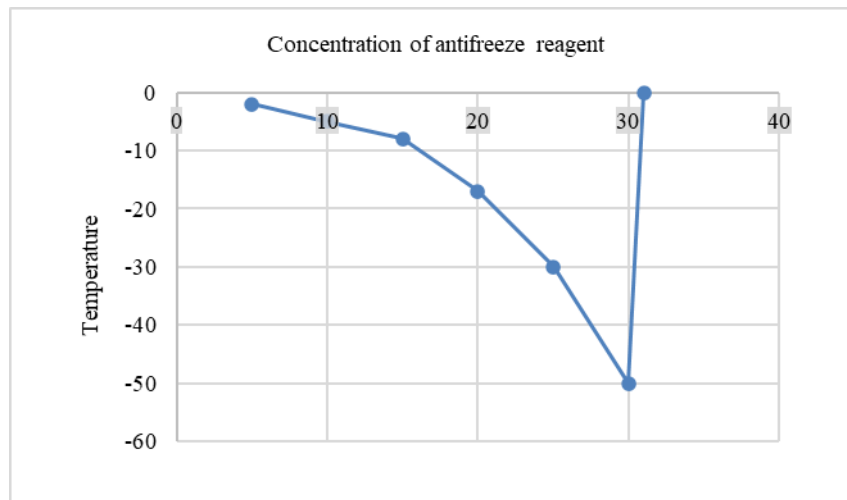


Figure 3. Gibbs diagram for antifreeze reagent

Before building the foundation of the structure, the top soil of construction site usually is subject to removing [15-33]. Consequently, the antifreeze reagent is spread on the second layer, which in this case, it is sandy loam. From the geological investigation, all the characteristics of this layer are known [34-56]. Sandy loam edQIII-IV – characterized by the following indicators of physical and mechanical properties given in Table 1.

Table 1. Physical and mechanical properties of sandy loam

No.	The name of indicators	unit of measurements	Limit values		Average (normative) values
			min	max	
1	Natural humidity	%	6.25	8.0	6.74
2	Humidity in the yield strength	%	15.5	18.0	17.0
3	Moisture at rolling limit	%	13.5	15.2	14.4
4	Plasticity number	%	1.2	4.0	2.5
5	Consistency		0.28	0.81	0.60
6	Soil density	g/cm ³	1.60	2.01	1.79
7	Density of soil particles	g/cm ³	2.35	2.80	2.59
8	Porosity coefficient	share units	0.385	0.686	0.542
9	Moisture degree	share units	0.256	0.440	0.326
10	Specific adhesion	kPa	39.6	47	44.5
11	Angle of internal friction	degree	24.2	27.0	26.4
12	Deformation modulus (compression at natural moisture)	MPa	34.5	42	39.8

According to the SNIIP 23-01-99 the average temperature of coldest five days in Nur-Sultan city is -37°C. Normative frozen ground depth is 205 cm according to SP RK 2.04-01-2017. The amount of antifreeze reagent was also calculated and was taken for this temperature. Considering the prevention of the frozen ground, it is enough to protect the first 10 centimeters of the surface of the soil [57-74]. The equation for the determination of antifreeze reagent for 1m³ of soil surface will be:

$$\rho = 1.79 \text{ g/cm}^3, \quad (1)$$

$$M_w = 0.37 \text{ g/cm}^3, \quad (2)$$

where: ρ =density of the soil; $C_{anti.r}$ =concentration of antifreeze reagent; M_w =mass of water in soil; $m_{anti.r}$ =mass of antifreeze reagent. In 1m³ of soil, there is 37 kg of water.

$$m_{\text{anti.r.}} = \frac{C_{\text{anti.r.}} * M_{\text{water}}}{100\% - C} \tag{3}$$

where: $C_{\text{anti.r.}} = 25\%$ at the temperature -30°C :

$$m_{\text{anti.r.}} = \frac{25\% * 37 \text{ kg}}{100\% - 25\%} = 12.3 \text{ kg.} \tag{4}$$

Locally for each pile with the size of 40x40, the mass of antifreeze reagent will be as follows:

$$0.4 * 0.4 = 0.16 \text{ m}^2, \tag{5}$$

$$12.3 \text{ kg} * 0.16 \text{ m}^2 = 1.79 \text{ kg.} \tag{6}$$

3. Results and discussion

The first box with antifreeze reagent has been kept and monitored for 15 days at the freezing camera. The soil was soft, so the antifreeze reagent prevented the whole soil in the box from freezing. The plastic pile was easily driven by the hummer in 13 hits. The results can be seen at the Figure 4.

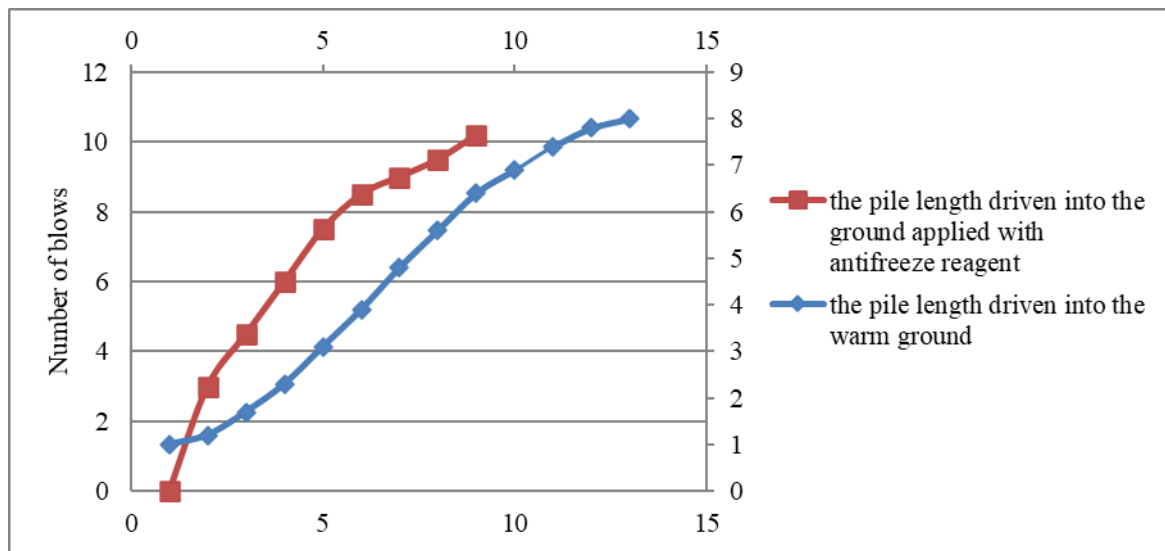


Figure 4. Depth of model pile (cm)

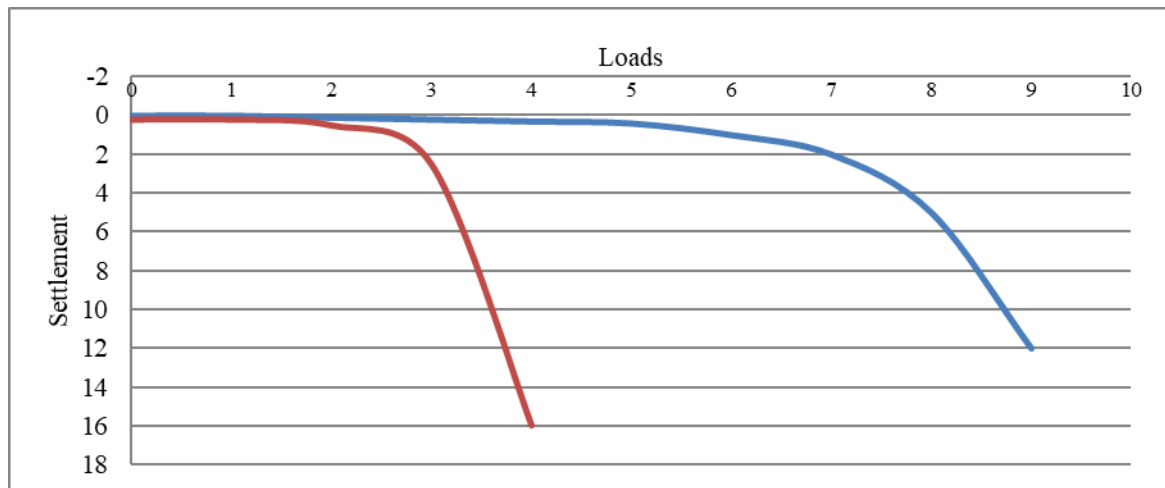


Figure 5. The results of static load test

Moreover, the piles were tested for static load test in the freezer camera under different load conditions and in constant loads (increasing in steps) (Figure 5). The ruler was used to measure the settlements of the pile. As for loads, the dumbbells were used with different weights of 1 kg, 2 kg, 4 kg, 5 kg, 6 kg, and 8 kg. The pile has started to settle from 4 kg for 0.1 mm, and at the 8 kg it was totally went into the soil. The second box which was kept at the room temperature +18°C has also been tested for static load test. The pile was fully driven in 8 hits by a hummer [75-97]. The third box which was put to freezer without an antifreeze reagent was fully frozen. The pile could not be driven after 100 hits and even after boring it for 5 cm. The head of the plastic pile was damaged by a lot of hits. The soil was thick [10]. At the construction site, the method of doing experiment a little different as the soil ground was already frozen and covered by snow. The outdoor temperature was -25°C. The antifreeze reagent was put locally in places of two piles (Figure 6). The aim of this experiment is to see the effect of antifreeze reagent whether it thaws the already frozen soil. After putting the reagent, the places of piles were constantly monitored. At the first day of experiment, it has been noticed that the snow on the surface of the soil was fully melted (Figure 7). At the third day, the depth of thawing soil reached 3 cm (Figure 8).



Figure 6. An antifreeze reagent on frozen ground



Figure 7. Measuring the thawed depth first day



Figure 8. Measuring the thawed depth third day

After 14 days the depth of thawed soil was 10 cm. Outdoor temperature was -27°C in day time, and -30°C at night. The soil ground on surface was soft and wet. It has been decided to drive one of the piles without boring in these places as there were some thawing results. Number of hits on already drilled places was 198, while on thawed ground this number was 200. The number of hits in two different methods was similar which proves the effectiveness of using antifreeze reagent even in frozen ground [98-117].

The piles have been tested for bearing capacity. These tests were carried out according to the requirements of GOST 5686-2012 “Soils. Field test methods with piles” [118]. The load on the pile was created using a 100-ton hydraulic jack “Enerpred DU100P150” with a pumping station “Enerpac P462”, abutting against a test and loading stand, weighing 120.0 tons. The load was recorded with a pressure gauge up to 1000 atm (kgf / cm²) of the MA100VU100 type with a graduation rate of 20 atm (kgf / cm²) and a digital dynamometer of the “Load Cell” type connected to the SLT2 monitoring system. The settlement of each pile was measured by two 6PAO deflection meters with a scale division of 0.01 mm, and also by four digital electronic displacement transducers of the type 027DG1, 027DG2, 027DG3, 027DG4 working in conjunction with SLT2. The piles were tested with static stepwise increasing loads, the first five steps of 120 kN (80 atm), then 60 kN (40 atm) and were brought to a maximum load of 840 kN (for piles No. 62), and for piles No. 66 up to a maximum load of 960 kN. With the maximum applied load on pile No. 62 equal to 840 kN, on pile No. 66 equal to 960 kN, the displacements of the piles were 48.01 mm, 40.14 mm, respectively (Figures 9, 10).

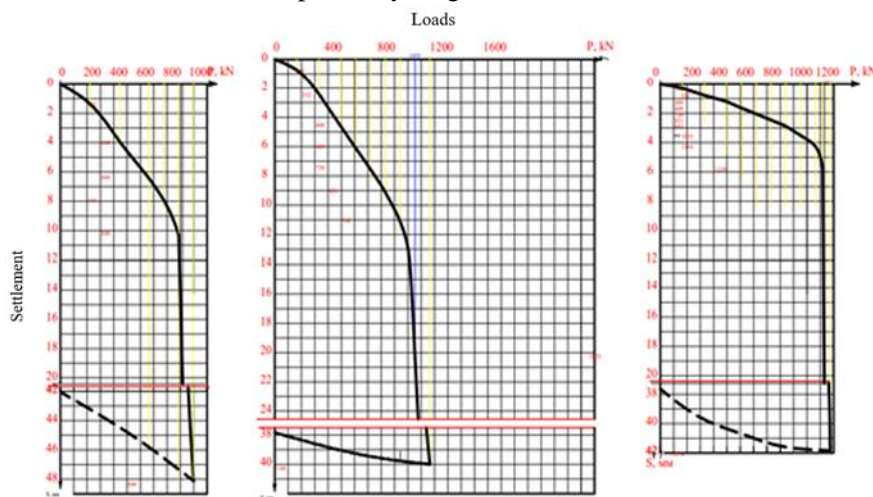


Figure 9. Results of Static Load Test: settlement of pile No. 62

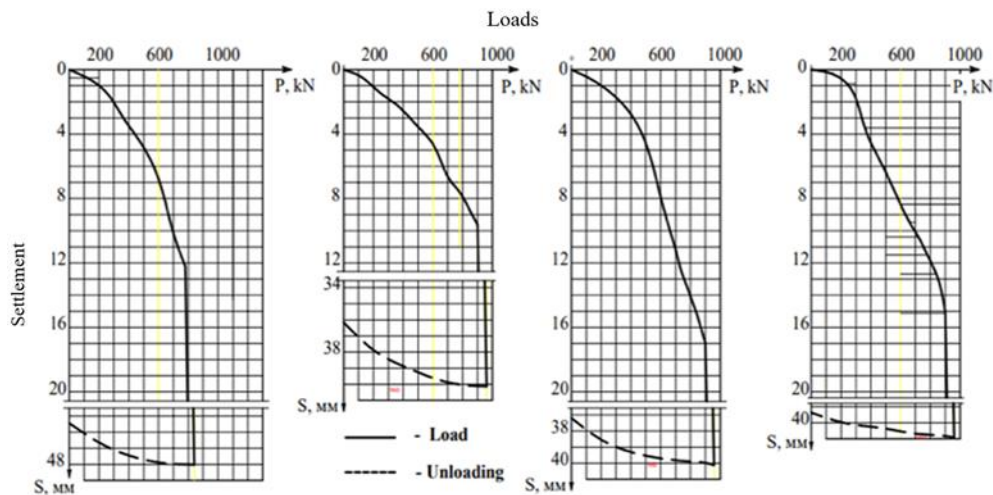


Figure 10. Results of Static Load Test: settlement of pile No. 66

Each pile was unloaded in double steps with observation of each unloading step for at least 15 minutes. After complete unloading (to zero), observation of the elastic displacements of the pile was carried out for 60 minutes, with the movement of the piles being recorded every 15 minutes. The bearing capacity of the piles, according to the results of their static load tests at the above construction site, were: 780 kN and 900 kN.

4. Conclusions

1. It has been identified the protecting effect of antifreeze reagent from soil freezing in winter.
2. Implementation of the proposed method leads to the high productivity driving of reinforced concrete piles without the risk of their destruction.
3. Moreover, there is no need on additional drilling works and more powerful and expensive hammers for driving piles if the soil has been protected from freezing.
4. The given formula of calculating the mass of antifreeze reagent can protect the soil without harming not only the soil but also the structure of concrete pile and environment.
5. The comparison of two model box tests has been proved the effectiveness of antifreeze reagent which eases the penetration of piles into the ground in winter time.
6. The thawing effect of antifreeze reagent on already frozen soils has been found out during the experiment.
7. It has been possible to test the piles for static load test in winter time as there was thawing effect from the used reagent.
8. During the static load test, piles that are driven into the soil where the antifreeze reagent was applied have shown more accurate bearing capacity data.
9. It has been identified that the antifreeze reagent decreases the compressibility of frozen soil.

References

- [1] H. Vaziri and Y. Han, "Full-scale field studies of the dynamic response of piles embedded in partially frozen soils", *Canadian Geotechnical Journal*, vol. 28, pp. 708-718, 1991.
- [2] Z. Xing, D. He, H. Wang, Z. Ye and S. Yang, "Study on soil mechanics and frost resistance of fly ash-metakaolin geopolymer", *Arabian Journal of Geosciences*, vol. 13, no. 18, article number 963, 2020.
- [3] F. Xiao, G. S. Chen, J. L. Hulse, D. Davis and Z. Yang, "Characterization of the viscoelastic effects of thawed frozen soil on pile by measurement of free response", *Cold Regions Science and Technology*, vol. 145, pp. 229-236, 2018.
- [4] Z. J. Yang, X. R. Zhang, R. Yang, X. Zhou and F. Niu, "Shake table modeling of pile foundation performance in laterally spreading frozen ground crust overlying liquefiable soils", *Journal of Cold Regions Engineering*, vol. 32, no. 4, article number 04018012, 2018.

-
- [5] G. S. Crowther, "Lateral pile analysis frozen soil strength criteria", *Journal of Cold Regions Engineering*, vol. 29, no. 2, article number 04014011, 2015.
- [6] L. M. Wotherspoon, S. Sritharan and M. J. Pender, "Modelling the response of cyclically loaded bridge columns embedded in warm and seasonally frozen soils", *Engineering Structures*, vol. 32, no. 4, pp. 933-943, 2010.
- [7] J. S. Weaver and N. R. Morgenstern, "Pile design in permafrost", *Canadian Geotechnical Journal*, vol. 18, no. 3, pp. 357-370, 1981.
- [8] Y. Y. Velli and A. A. Karpunia, Saline permafrost as bearing ground for construction, Washington: National Academy of Sciences, 1973.
- [9] Zh. H. J. Yang, Q. Li, E. E. Marx and J. Ch. Lu, "Seasonally frozen soil effects on the dynamic behavior of highway bridges", *Sciences in Cold and Arid Regions*, vol. 4, no. 1, pp. 13-20, 2012.
- [10] O. B. Andersland and B. Ladanyi, Frozen ground engineering, New York: John Wiley & Sons, 2004.
- [11] L. U. Arenson, S. M. Springman and D. C. Sego, "The rheology of frozen soils", *Applied Rheology*, vol. 17, pp. 1-14, 2007.
- [12] N. Ogata, M. Yasuda and T. Kataoka, "Effects of salt concentration on strength and creep behavior of artificially frozen soils", *Cold Regions Science and Technology*, vol. 8, pp. 139-153, 1983.
- [13] A. K. Kiyalbayev and A. S. Yerkiybayeva, "Technological features of the use of chemical reagents to combat slipperiness on highways when emergency distribution method", *Science News of Kazakhstan*, vol. 3, pp. 114-120, 2004.
- [14] A. Sarsembayeva and A. Zhussupbekov, "Experimental study of dicing chemical redistribution and moisture mass transfer in highway subsoils during the unidirectional freezing", *Transportation Geotechnics*, vol. 26, article number 100426, 2021.
- [15] M. Kuprikov, L. N. Rabinskiy, "Vertical take-off and landing aircrafts: myth or reality of modern aviation," *Journal of Mechanical Engineering Research and Developments*, vol. 41, no. 4, pp. 46-52, 2018.
- [16] A. G. Getmanov, L. N. Rabinskiy, "Assessment of durability of coatings in difficult stress conditions," *Periodico Tche Quimica*, vol. 16, no. 33, pp. 490-497, 2019.
- [17] M. Kuprikov, L. N. Rabinskiy, "Influence of infrastructure constraints on the geometrical layout of a long-haul aircraft," *Journal of Mechanical Engineering Research and Developments*, vol. 41, no. 4, pp. 40-45, 2018.
- [18] R. R. Anamova, L. V. Bykov, D. A. Kozorez, "Algorithm for designing professional retraining programs based on a competency approach," *Education Sciences*, vol. 10, no. 8, pp. 1-9, 2020.
- [19] M. Kuprikov, L. N. Rabinskiy, "Cross-polar routes as a factor that changed the geometric layout of long-haul aircrafts flying over long distances," *Journal of Mechanical Engineering Research and Developments*, vol. 41, no. 4, pp. 53-57, 2018.
- [20] M. Y. Kuprikov, N. M. Kuprikov, L. N. Rabinskiy, "The dependence of the appearance of the aircraft on the conditions of the arctic basing," *INCAS Bulletin*, vol. 11, pp. 115-123, 2019.
- [21] O. V. Egorova, Y. K. Kyaw, "Solution of inverse non-stationary boundary value problems of diffraction of plane pressure wave on convex surfaces based on analytical solution," *Journal of Applied Engineering Science*, vol. 18, no. 4, pp. 676-680, 2020.
- [22] V. A. Zagovorchev, O. V. Tushavina, "The use of jet penetrators for movement in the lunar soil," *INCAS Bulletin*, vol. 11, pp. 121-130, 2019.
- [23] V. A. Zagovorchev, O. V. Tushavina, "Selection of temperature and power parameters for multi-modular lunar jet penetrator," *INCAS Bulletin*, vol. 11, pp. 231-241, 2019.
- [24] S. Vakhneev, E. Starovoitov, "Damping of circular composite viscoelastic plate vibration under neutron irradiation," *Journal of Applied Engineering Science*, vol. 18, no. 4, pp. 699-704, 2020.
- [25] Y. Sun, M. Y. Kuprikov, E. L. Kuznetsova, "Effect of flight range on the dimension of the main aircraft," *INCAS Bulletin*, vol. 12, pp. 201-209, 2020.
-

-
- [26] Y. Li, A. M. Arutiunian, E. L. Kuznetsova, G. V. Fedotenkov, "Method for solving plane unsteady contact problems for rigid stamp and elastic half-space with a cavity of arbitrary geometry and location," *INCAS Bulletin*, vol. 12, pp. 99-113, 2020.
- [27] E. L. Kuznetsova, G. V. Fedotenkov, E. I. Starovoitov, "Methods of diagnostic of pipe mechanical damage using functional analysis, neural networks and method of finite elements," *INCAS Bulletin*, vol. 12, pp. 79-90, 2020.
- [28] D. A. Kozorez, E. A. Dolgova, A. V. Korneenkova, A. V. Rumakina, M. Sha, "Higher education institutions educational process digitalization in the context of the necessity to provide a model for students' choice of training areas and academic specialties," *International Journal of Criminology and Sociology*, vol. 9, pp. 3033-3039, 2020.
- [29] E. V. Akimov, D. A. Kozorez, D. M. Kruzhhkov, "Navigation solution concept and its practical approach development for lunar missions," *Russian Engineering Research*, vol. 40, no. 7, pp. 605-607, 2020.
- [30] A. E. Sorokin, S. V. Novikov, "Formation of the national economy of Russia in the context of state support of innovation actions," *Espacios*, vol. 40, no. 38, pp. 1-9, 2019.
- [31] N. S. Kudryavtseva, A. E. Sorokin, "Comparative reliability assessment and costing of life support systems for extended interplanetary missions," *Aviakosmicheskaya i Ekologicheskaya Meditsina*, vol. 54, no. 2, pp. 30-37, 2020.
- [32] E. E. Galkina, A. E. Sorokin, "Quality management and sustainable economic development," *Russian Engineering Research*, vol. 40, no. 7, pp. 577-578, 2020.
- [33] V. V. Bodryshev, L. G. Nartova, L. N. Rabinskiy, "Digital interpretation of gas dynamics problems as a means of optimizing fundamental general engineering education," *Asia Life Sciences*, vol. 2, pp. 759-774, 2019.
- [34] V. V. Bodryshev, A. A. Larin, L. N. Rabinsky, "Flaw detection method for radomes in weakly anechoic conditions," *TEM Journal*, vol. 9, no. 1, pp. 169-176, 2020.
- [35] V. V. Bodryshev, N. P. Korzhov, L. N. Rabinskiy, "Grapho-analytical analysis of video frames of supersonic flow around two solid revolutions using the digital image processing method," *TEM Journal*, vol. 9, no. 2, pp. 449-459, 2020.
- [36] V. S. Terentieva, A. N. Astapov, "Conceptual protection model for especially heat-proof materials in hypersonic oxidizing gas flows," *Russian Journal of Non-Ferrous Metals*, vol. 59, no. 6, pp. 709-718, 2018.
- [37] V. S. Terentieva, A. N. Astapov, L. N. Rabinskiy, "State in the field of heat-resistant coatings for heat-proof nickel alloys and steels," *Periodico Tche Quimica*, vol. 16, no. 33, pp. 561-572, 2019.
- [38] V. A. Pogodin, A. N. Astapov, L. N. Rabinskiy, "CCCM specific surface estimation in process of low-temperature oxidation," *Periodico Tche Quimica*, vol. 17, no. 34, pp. 793-802, 2020.
- [39] V. A. Pogodin, L. N. Rabinskii, S. A. Sitnikov, "3D printing of components for the gas-discharge chamber of electric rocket engines," *Russian Engineering Research*, vol. 39, no. 9, pp. 797-799, 2019.
- [40] N. S. Severina, "Software complex for solving the different tasks of physical gas dynamics," *Periodico Tche Quimica*, vol. 16, no. 32, pp. 424-436, 2019.
- [41] A. V. Babaytsev, L. N. Rabinskiy, K. T. Aung, "Investigation of the contact zone of a cylindrical shell located between two parallel rigid plates with a gap," *INCAS Bulletin*, vol. 12, pp. 43-52, 2020.
- [42] A. V. Babaytsev, L. N. Rabinskiy, "Design calculation technique for thick-walled composite constructions operating under high-speed loading," *Periodico Tche Quimica*, vol. 16, no. 33, pp. 480-489, 2019.
- [43] A. V. Babaytsev, Y. K. Kyaw, S. N. Vakhneev, T. Zin Hein, "Study of the influence of spherical inclusions on mechanical characteristics," *Periodico Tche Quimica*, vol. 17, no. 35, pp. 654-662, 2020.
- [44] A. V. Babaytsev, A. A. Zotov, "Designing and calculation of extruded sections of an inhomogeneous composition," *Russian Metallurgy (Metally)*, vol. 2019, no. 13, pp. 1452-1455, 2019.
-

-
- [45] A. V. Babaytsev, A. A. Orekhov, L. N. Rabinskiy, "Properties and microstructure of $alsi_{10}mg$ samples obtained by selective laser melting," *Nanoscience and Technology*, vol. 11, no. 3, pp. 213-222, 2020.
- [46] V. V. Bodryshev, A. V. Babaytsev, L. N. Rabinskiy, "Investigation of processes of deformation of plastic materials with the help of digital image processing," *Periodico Tche Quimica*, vol. 16, no. 33, pp. 865-876, 2019.
- [47] V. A. Korolenko, Y. Li, V. N. Dobryanskiy, Y. O. Solyaev, "Experimental studies and modelling of fracture toughness of the epoxy samples with eccentric cracks," *Journal of Applied Engineering Science*, vol. 18, no. 4, pp. 719-723, 2020.
- [48] M. Sha, O. A. Prokudin, Y. O. Solyaev, S. N. Vakhneev, "Dependence of glare destruction mechanisms on the elongation of samples in tests to three-point flexural," *Periodico Tche Quimica*, vol. 17, no. 35, pp. 549-558, 2020.
- [49] A. Babaytsev, V. Dobryanskiy, Y. Solyaev, "Optimization of thermal protection panels subjected to intense heating and mechanical loading," *Lobachevskii Journal of Mathematics*, vol. 40, no. 7, pp. 887-895, 2019.
- [50] S. A. Lurie, P. A. Belov, Y. O. Solyaev, E. C. Aifantis, "On one class of applied gradient models with simplified boundary problems," *Materials Physics and Mechanics*, vol. 32, no. 3, pp. 353-369, 2017.
- [51] Yu. G. Evtushenko, V. I. Zubov, S. A. Lurie, Yu. O. Solyaev, "Identification of kinetic parameters of the model of interphase layer growth in a fibrous composite," *Composites: Mechanics, Computations, Applications*, vol. 7, no. 3, pp. 175-187, 2016.
- [52] E. L. Kuznetsova, A. V. Makarenko, "Mathematic simulation of energy-efficient power supply sources for mechatronic modules of promising mobile objects," *Periodico Tche Quimica*, vol. 15, no 1, pp. 330-338, 2018.
- [53] Y. K. Kyaw, E. L. Kuznetsova, A. V. Makarenko, "Complex mathematical modelling of mechatronic modules of promising mobile objects," *INCAS Bulletin*, vol. 12, pp. 91-98, 2020.
- [54] D. V. Topchiy, A. S. Bolotova, "The monolithic buildings complex renovation's organizational and technological model creation," *IOP Conference Series: Materials Science and Engineering*, vol. 913, no. 4, 042016, 2020.
- [55] D. Topchiy, A. Bolotova, "Risk management in monolithic construction," *IOP Conference Series: Materials Science and Engineering*, vol. 962, no. 2, 022078, 2020.
- [56] D. Topchiy, A. Bolotova, "Systematization of Factors Affecting the Organizational Processes in the Conversion of Buildings," *IOP Conference Series: Materials Science and Engineering*, vol. 753, no. 3, 032042, 2020.
- [57] K. Imanbayev, B. Sinchev, S. Sibabayeva, A. Mukhanova, A. Nurgulzhanova, N. Zaurbekov, N. Zaurbekova, N. V. Korolyova, L. Baibolova, "Analysis and mathematical modeling of big data processing," *Peer-to-Peer Networking and Applications*, vol. 1, pp. 1-10, 2020.
- [58] D. Topchiy, A. Bolotova, "Assessment and Inspection of the Technical Condition of Monolithic Reinforced Structures in Transportation Infrastructure Facilities," *Journal of Physics: Conference Series*, vol. 1425, no. 1, 012005, 2020.
- [59] A. Tokarskiy, D. Topchiy, "State Construction Supervision during Repurposing Project Implementation in the Urban Areas," *IOP Conference Series: Materials Science and Engineering*, vol. 698, no. 6, 066061, 2019.
- [60] Yu. M. Koval, V. Z. Kutsova, M. A. Kovzel, P. Yu. Shvets, "Features of Structure Formation, Kinetics of Phase Transformations, Mechanical and Tribological Properties of the Fe-based Cr-Mn-Ni Alloys," *Progress in Physics of Metals*, vol. 21, no. 2, pp. 180-248, 2020.
- [61] D. Topchiy, A. Bolotova, "Studying Specific Features of the Monolithic Construction Technology Based on Systemic Analysis," *IOP Conference Series: Materials Science and Engineering*, vol. 603, no. 5, 052004, 2019.
-

- [62] V. Klimina, A. Yurgaitis, D. Topchiy, "Unified Classification of Defects Detected by the Technical Examination," *E3S Web of Conferences*, vol. 110, 01086, 2019.
- [63] A. Lapidus, D. Topchiy, "Construction supervision at the facilities renovation," *E3S Web of Conferences*, vol. 91, 08044, 2019.
- [64] R. R. Anamova, A. V. Ripetskiy, "Waveguide Transmission Lines: Some Issues of Automated Designing," in *CriMiCo 2013 – 2013 23rd International Crimean Conference Microwave and Telecommunication Technology, Conference Proceedings*, Sevastopol, Ukraine, pp. 626-627, 2013.
- [65] A. Jurgaitis, D. Topchiy, A. Kravchuk, D. Shevchuk, "Controlling methods of buildings' energy performance characteristics," *E3S Web of Conferences*, vol. 91, 02026, 2019.
- [66] R. R. Anamova, "Antenna Arrays: Waveguide Layout Designing Automation," in *2013 9th International Conference on Antenna Theory and Techniques, ICATT 2013*, Odessa, Ukraine, pp. 258-260, 2013.
- [67] D. V. Topchy, "Formation of organizational and technological systems for renovation of production facilities located on the territory of megacities," *International Journal of Civil Engineering and Technology*, vol. 9, no. 8, pp. 1452-1457, 2018.
- [68] D. Topchiy, A. Tokarskiy, "Formation of hierarchies in the organization system of the state construction supervision during reshaping of city territories," *International Journal of Engineering and Advanced Technology*, vol. 8, no. 4C, pp. 44-46, 2019.
- [69] A. M. Nesterenko, V. Z. Kutsova, M. A. Kovzel, "Investigation of crystal structure of Me7C3-type carbides," *Metallofizika i Noveishie Tekhnologii*, vol. 25, no. 1, pp. 99-106, 2003.
- [70] D. V. Topchiy, A. S. Bolotova, A. A. Zelentsov, A. S. Vorobev, A. V. Atamanenko, "Technical rationing of the construction technology of reinforced concrete floor slabs using non-removable empitness-liners," *International Journal of Civil Engineering and Technology*, vol. 10, no. 2, pp. 2160-2166, 2019.
- [71] N. S. Buktukov, B. Z. Buktukov, G. Z. Moldabayeva, "Sail-aerodynamic wind power station with automatically changing blade-swept area," *International Journal of Mechanical and Production Engineering Research and Development*, vol. 10, no. 3, pp. 911-920, 2020.
- [72] D. Topchiy, A. Tokarskiy, "Formation of hierarchies in the system of organization of state construction supervision in case of reorientation of urban areas," *Communications in Computer and Information Science*, vol. 1046, pp. 134-143, 2019.
- [73] A. Kairbayeva, V. Vasilenko, S. Dzhinguilbayev, L. Baibolova, L. Frolova, "Development of the mathematical model for the process of oil raw materials pressing," *International Journal of Engineering and Technology (UAE)*, vol. 7, pp. 145-149, 2018.
- [74] D. Y. Savon, A. V. Aleksakhin, O. O., Skryabin, A. A. Goodilin, "Occupational health and safety digitalization in the coal industry," *Eurasian Mining*, vol. 2019, no. 2, pp. 70-72, 2019.
- [75] M. Y. Kizatova, Y. B. Medvedkov, A. A. Shevtsov, A. V. Drannikov, D. A. Tlevlesova, "Experimental-statistical analysis and multifactorial process optimization of the crust from melon pulp separation process," *Journal of Engineering and Applied Sciences*, vol. 12, no. 7, pp. 1762-1771, 2017.
- [76] M. K. Alimardanova, D. A. Tlevlesova, Z. Simov, D. Dimitrov, A. I. Matibayeva, "Incorporating Allium odorum as a vegetable ingredient of processed cheeses," *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, vol. 6, no. 3, pp. 330-338, 2015.
- [77] D. V. Topchy, "Organisational and technological measures for converting industrial areas within existing urban construction environments," *International Journal of Civil Engineering and Technology*, vol. 9, no. 7, pp. 1975-1986, 2018.
- [78] A. Lapidus, T. Dmitry, "Formation of Methods for Assessing the Effectiveness of Industrial Areas' Renovation Projects," *IOP Conference Series: Materials Science and Engineering*, vol. 471, no. 2, 022034, 2019.
- [79] I. Katranov, A. Lapidus, "Mobile Building Life Cycle," *MATEC Web of Conferences*, vol. 193, 03011, 2018.

- [80] A. Lapidus, A. Makarov, "Statistical Learning Problem of Artificial Neural Network to Control Roofing Process," *MATEC Web of Conferences*, vol. 117, 00100, 2017.
- [81] A. Lapidus, A. Makarov, "Automation of Roof Construction Management by Means Artificial Neural Network," *Advances in Intelligent Systems and Computing*, vol. 692, pp. 1168-1176, 2018.
- [82] A. Lapidus, Y. Shesterikova, "Mathematical Model for Assessing the High-Rise Apartment Buildings Complex Quality," *E3S Web of Conferences*, vol. 91, 02025, 2019.
- [83] A. Lapidus, A. Khubaev, T. Bidov, "Development of a Three-Tier System of Parameters in the Formation of the Organizational and Technological Potential of Using Non-Destructive Testing Methods," *E3S Web of Conferences*, vol. 97, 06037, 2019.
- [84] A. A. Lapidus, I. L. Abramov, "Systemic integrated approach to evaluating the resource potential of a construction company as a bidder," *IOP Conference Series: Materials Science and Engineering*, vol. 603, no. 5, 052079, 2019.
- [85] A. Vlasyuk, V. Zhukovskyy, N. Zhukovska, H. Rajab, "One-Dimensional Modeling of Contaminant Migration in Unsaturated Porous Media with Dispersed Catalyst Particles," in *Proceedings – 2nd International Conference on Mathematics and Computers in Science and Engineering, MACISE 2020*, Madrid, Spain, pp. 197-201, 2020.
- [86] V. I. Ivin, V. V. Ryndin, "Unsteady flow in branched ducts of inlet pipes of internal combustion engines," *Izv Vyssh Uchebn Zaved Mashinostr*, vol. 9, pp. 100-105, 1976.
- [87] V. V. Ryndin, "Mathematical modeling of the process of filling an engine through an inlet manifold," *Izvestia vyssih ucebnyh zavedenij. Masinostroenie*, vol. 2, pp. 71-75, 1980.
- [88] O. Zh. Rabat, D. Absametov, M. M. Kunelbayev, E. L. Hasanov, D. V. Mykhalevskiy, R. N. Abdrashitova, Y.I. Salnikova, "Performance calculation of solar water heating unit at a petrol filling station," *Periodico Tche Quimica*, vol. 15, no. 30, pp. 589-598, 2018.
- [89] A. A. Lapidus, N. Yves, "Integrated quality index of organizational and technological solutions for implementation of Burundian capital master plan," *Materials Science Forum*, vol. 931, pp. 1295-1300, 2018.
- [90] G. Zh. Moldabayeva, R. T. Suleimenova, M. F. Turdiyev, Zh. B. Shayakhmetova, A. S. Karimova, "Scientific and technical substantiation of reducing oil viscosity," *International Journal of Engineering Research and Technology*, vol. 13, no. 5, pp. 967-972, 2020.
- [91] A. Lapidus, I. Abramov, "An assessment tool for impacts of construction performance indicators on the targeted sustainability of a company," *IOP Conference Series: Materials Science and Engineering*, vol. 753, no. 4, 042089, 2020.
- [92] E. S. Temirbekov, N. S. Zaurbekov, G. N. Zaurbekova, "Strength of bearing elements of falsework PMD-5.2M," *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Teknologiya Tekstil'noi Promyshlennosti*, vol. 2016, no. 4, pp. 125-130, 2016.
- [93] V. V. Ryndin, "Application of the postulate of nonequilibrium to calculate the nonequilibrium of systems of dissimilar gases and liquids," *Periodico Tche Quimica*, vol. 17, no. 34, pp. 998-1011, 2020.
- [94] R. R. Anamova, L. V. Bykov, D. A. Kozorez, "Algorithm for designing professional retraining programs based on a competency approach" *Education Sciences*, vol. 10, no. 8, pp. 1-9, 2020.
- [95] R. R. Anamova, S. A. Leonova, L. G. Nartova, V. P. Tereshchenko, "Digital spatial models in technology as a development tool of the intellectual creative aspect within education," *TEM Journal*, vol. 9, no. 3, pp. 1186-1193, 2020.
- [96] K. Sultanov, B. Khusanov, B. Rikhsieva, "Underground pipeline reliability under longitudinal impact load," *IOP Conference Series: Materials Science and Engineering*, vol. 869, no. 5, 052008, 2020.
- [97] K. Sultanov, B. Khusanov, B. Rikhsieva, "Shear waves around an underground pipeline," *IOP Conference Series: Materials Science and Engineering*, vol. 869, no. 5, 052016, 2020.
- [98] S. G. Gendler, M. L. Rudakov, L. Yu. Samarov, "Experience and prospects of occupational and industrial safety control in mineral mining and processing," *Gornyi Zhurnal*, vol. 2015, no. 5, pp. 84-87, 2015.

- [99] I. K. Sagynganova, A. I. Kvasov, A. A. Kalinin, "Comprehensive methods to obtain and process information flows in centralized heat supply systems," *IOP Conference Series: Materials Science and Engineering*, vol. 972, no. 1, 012074, 2020.
- [100] A. Baklanov, O. Baklanova, S. Grigoryeva, S. Kumargazhanova, I. Sagynganova, Y. Vais, G. Györök, "The development of hybrid IP architecture for solving the problems of heating networks (Using pipeline-parallel data processing technology)," *Acta Polytechnica Hungarica*, vol. 17, no. 1, pp. 123-140, 2020.
- [101] S. Kukharets, G. Golub, O. Skydan, Y. Yarosh, M. Kukharets, "Justification of Air Flow Speed in the Oxidation Area of a Gasifier in Case of Straw Pellets Using," *INMATEH – Agricultural Engineering*, vol. 60, no. 1, pp. 37-44, 2020.
- [102] S. Z. Mirzaev, U. Kaatze, "Scaling function of critical binary mixtures: Nitrobenzene-n-hexane data revisited," *Chemical Physics*, vol. 393, no. 1, pp. 129-134, 2012.
- [103] G. Golub, O. Skydan, V. Kukharets, Y. Yarosh, S. Kukharets, "The estimation of energetically self-sufficient agroecosystem's model," *Journal of Central European Agriculture*, vol. 21, no. 1, pp. 168-175, 2020.
- [104] E. V. Archinova, K. S. Mokeeva, T. O. Bunkova, R. O. Zhilisbayeva, "Evaluation of Operational Reliability of the Bullet-Proof Vest for Dogs of Office and Search Breeds," *Izvestiya Vysshikh Uchebnykh Zavedenii, Seriya Tekhnologiya Tekstil'noi Promyshlennosti*, vol. 371, no. 5, pp. 69-72, 2017.
- [105] V. V. Savinkin, P. Vitureanu, A. V. Sandu, T. Y. Ratushnaya, A. A. Ivanishev, A. Surleva, "Improvement of the turbine blade surface phase structure recovered by plasma spraying," *Coatings*, vol. 10, no. 1, 62, 2020.
- [106] G. Golub, S. Kukharets, O. Skydan, Y. Yarosh, V. Chuba, V. Golub, "The Optimization of the Gasifier Recovery Zone Height when Working on Straw Pellets," *International Journal of Renewable Energy Research*, vol. 10, no. 2, pp. 529-536, 2020.
- [107] V. V. Savinkin, T. Yu. Ratushnaya, A. A. Ivanishev, A. R. Surleva, O. V. Ivanova, S. N. Kolisnichenko, "Study on the optimal phase structure of recovered steam turbine blades using different technological spray modes for deposition of Al₂O₃," *AIP Conference Proceedings*, vol. 2129, 020022, 2019.
- [108] G. Golub, S. Kukharets, J. Česna, O. Skydan, Y. Yarosh, M. Kukharets, "Research on Changes in Biomass During Gasification," *INMATEH – Agricultural Engineering*, vol. 61, no. 2, pp. 17-24, 2020.
- [109] A. Baibatsha, "Geotectonics and geodynamics of paleozoic structures from the perspective of plume tectonics: A case of Kazakhstan," *International Journal of GEOMATE*, vol. 17, no. 71, pp. 194-202, 2020.
- [110] S. Z. Mirzaev, U. Kaatze, "Dynamic Scaling in the Ultrasonic Attenuation Spectra of Critical Binary Mixtures," *Chemical Physics Letters*, vol. 328, no. 3, pp. 277-282, 2000.
- [111] G. A. Golub, O. V. Skydan, S. M. Kukharets, O. A. Marus, "Substantiation of Motion Parameters of the Substrate Particles in the Rotating Digesters," *INMATEH – Agricultural Engineering*, vol. 57, no. 1, pp. 179-186, 2019.
- [112] O. Skydan, B. Sheludchenko, S. Kukharets, O. Medvedskyi, Y. Yarosh, "Analytical study of multifractal invariant attributes of traffic flows," *Eastern-European Journal of Enterprise Technologies*, vol. 3, no. 3-99, pp. 22-29, 2019.
- [113] A. B. Baibatsha, A. Muszynski, "Geological-geophysical prospecting indicators of the arganaty district predictive blocks (Eastern Balkhash)," *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, vol. 2, no. 440, pp. 31-39, 2020.
- [114] V. N. Korzhyk, L. D. Kulak, V. E. Shevchenko, V. V. Kvasnitskiy, N. N. Kuzmenko, X. Liu, Y. X. Cai, L. Wang, H. W. Xie, L. M. Zou, "New equipment for production of super hard spherical tungsten carbide and other high-melting compounds using the method of plasma atomization of rotating billet," *Materials Science Forum*, vol. 898, pp. 1485-1497, 2017.

- [115] S. Peleshenko, V. Korzhyk, O. Voitenko, V. Khaskin, V. Tkachuk, “Analysis of the current state of additive welding technologies for manufacturing volume metallic products (review),” *Eastern-European Journal of Enterprise Technologies*, vol. 3, no. 1-87, pp. 42-52, 2017.
- [116] T. N. Melnichuk, S. F. Abdurashytov, E. E. Andronov, E. R. Abdurashytova, A. Y. Egovtseva, A. A. Gongalo, E. N. Turin, V. S. Pashtetskiy, “The taxonomic structure of southern chernozem at the genus level influenced by microbial preparations and farming systems,” *IOP Conference Series: Earth and Environmental Science*, vol. 22, no. 1, 012101, 2020.
- [117] E. Barbotkina, I. E. Dunaieva, V. Popovych, V. Pashtetsky, “Review of methods and approaches of abandoned lands identification,” *E3S Web of Conferences*, vol. 224, 04004, 2020.
- [118] GOST 5686-2012. Soils. Field test methods with piles. [Online]. Available: <https://files.stroyinf.ru/Data2/1/4293787/4293787541.pdf>, 2014.