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# DEFORMATIONS OF SOIL MASSES UNDER THE ACTION OF HUMAN-INDUCED FACTORS

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***Abstract.*** *Significant changes in the stress-strain state cause a change in the soil profile of the massif, which is affected by various physical and chemical factors. In particular, groundwater filtration, mass transfer, heat transfer, dissolution and leaching of soil masses. This can lead to various types of accidents. Therefore, the study of the stress-strain state of the soil massif is an important topic. Nonlinear dependences in the form of polynomials of the modulus of deformation and Lame coefficients on the concentration of salt solutions and their temperature have been received in this research based on experimental research and their statistical processing. This allowed improving the mathematical model of the stress-strain state of the soil taking into account the nonlinear deformation processes occurring in the soil masses under the presence and filtration of saline solutions in non-isothermal conditions.*

**Keywords**: mathematical models, statistical analysis, stress-strain state, deformation

## DEFORMACJE MASY GLEBY POD DZIAŁANIEM CZYNNIKÓW CZŁOWIEKA

***Streszczenie.*** *Znaczące zmiany stanu naprężeniowo-odkształceniowego powodują zmianę profilu glebowego masywu, na który wpływają różne czynniki fizyczne i chemiczne. W szczególności filtracja wód gruntowych, przenikanie masy, przenoszenie ciepła, rozpuszczanie i wymywanie mas glebowych. Może to prowadzić do różnego rodzaju wypadków. Dlatego ważnym tematem jest badanie stanu naprężeniowo-odkształceniowego masywu glebowego. W niniejszych badaniach otrzymano nieliniowe zależności w postaci wielomianów modułu odkształcenia i współczynników Lame'a od stężenia roztworów soli i ich temperatury w oparciu o badania eksperymentalne i ich obróbkę statystyczną. Pozwoliło to na udoskonalenie modelu matematycznego stanu naprężeniowo-odkształceniowego gruntu uwzględniającego nieliniowe procesy odkształceń zachodzących w masach gruntu pod wpływem obecności i filtracji roztworów soli w warunkach nieizotermicznych.*

**Słowa kluczowe**: modele matematyczne, analiza statystyczna, stan naprężenia-odkształcenia, odkształcenie

## Introduction

Human activity leads to changes in hydrogeological conditions [5, 12]. And the change in hydrogeological conditions on Earth is accelerating. The reason for such changes is the excessive strengthening of a previously unknown geological agent. This new geological agent is human activity. In the research paper [19], human technical activity is considered a driving geological force that not only changes the face of the earth's surface but also makes significant changes in the upper part of the earth's crust, which is comparable to scale and consequences with geological processes.

The problem is greatly complicated if the soil is contaminated with various solutions of industrial facilities' slurry ponds, which accumulate industrial waste. These objects often reach quite large sizes, and they constantly or periodically get a large amount of so-called "spent" liquids used in technological processes, which are characterized by high mineralization and temperature.

Currently, the data have been used which are developed for soil mechanics to assess the soil mass deformation which is saturated with saline solutions [8, 9]. And this is the subject to the action of low-concentration natural groundwater [4].

Also some researchers are working on geotechnical issues of landslides in Ukraine [11] and decreasing service life of buildings under the regular explosion loads [10]. At the same time others proved the theory that mining activities always have and exclusively caused considerable changes in the environment [7]. Moreover, the rapid growth of population, urban planning, agricultural and industrial sectors also may have a significant effect [2].

Scientists pay attention also to asphalt mixes. In paper [3] they developed mathematical models for not isothermal conditions of marginal soils deformation (foamed and emulsified sulfur asphalt soils mixes) using specific software. Paper [1] provides a new numerical model in discrete element analysis for simulating flow time and number tests of asphalt mixes.

However, our previous experiments have shown, the compressibility of soils subject to the action of saline solutions depends on many factors. It depends from the degree of load and the concentration of saline solutions and their temperature as well [13, 14, 17].

Human-induced impact on soil masses leads to various factors: hydrodynamic forces of the filtration flow, changes in the filtration and deformation characteristics of the soil and so on. The change of these factors can be important, which leads to significant deformations of the earth's surface [6, 21, 23]. These deformations complicate regular operation and, in some cases, lead to accidents of industrial and energetic objects and can cause significant economic damage and even victims. In difficult military times, the issue of the stress-deformation state of soil massifs also acquires new relevance. This especially applies to areas of hostilities affected by massive artillery strikes.

The work aims to study the influence of the concentration of salt solutions and their temperature on the deformation processes of the soil and to create on this basis a computational-theoretical apparatus for forecasting the deformations of soil masses.

## 1. Physical experiments

To establish the influence of solutions' concentration and their temperature on the deformation characteristics of the soil, experimental studies were conducted in the geotechnical laboratory of the National University of Water and Environmental Engineering (Rivne, Ukraine).

The experiments were performed on a compression-filtration device according to state standard methods [18]. Issued in January 1991 in Kyiv, this standard outlines the specific methods to accurately assess these soil properties, which are crucial for construction and engineering purposes. The standard ensures that soil testing is conducted consistently and reliably, providing essential data for evaluating soil behavior under various conditions, which is vital for the design and safety assessment of construction projects.

Soil samples of disturbed structures with specified values of density and humidity were used for analysis. The soils for the study were sandy clays with the number of plasticity $I_p$ = 7.0%, the porosity coefficient e = 0.55. Soil pastes for the experiment had been saturating with NaCl saline solutions' concentration 0; 22; 44; 65; 90; 110; 130; 145; 165 g/l for 2 days. The temperature value was taken in the range from 22°C to 88°C.

Results of experimental data have been shown in tables 1–3.

*Table 1. The value of the deformation modulus E(c, T)*

| c, g/l | Deformation modulus *E*(*c*, *T*), kPa | | | |
|---|---|---|---|---|
| | *T* = 22°C | *T* = 31°C | *T* = 60°C | *T* = 88°C |
| 0 | 6555 | 6003 | 5692 | 5117 |
| 22 | 5520 | 5290 | 5175 | 4743 |
| 44 | 5002 | 4887 | 4738 | 4427 |
| 65 | 5060 | 4773 | 4427 | 4140 |
| 90 | 5164 | 4876 | 4485 | 4025 |
| 110 | 5348 | 4922 | 4571 | 4111 |
| 130 | 5474 | 5060 | 4715 | 4312 |
| 145 | 5681 | 5232 | 4916 | 4571 |
| 165 | 6038 | 5462 | 5175 | 4830 |

*Table 2. The value of Lame parameter λ(c, T)*

| c, g/l | Lame parameter *λ*(*c*, *T*), kPa | | | |
|---|---|---|---|---|
| | *T* = 22°C | *T* = 31°C | *T* = 60°C | *T* = 88°C |
| 0 | 5663 | 5187 | 4918 | 4422 |
| 22 | 4770 | 4571 | 4471 | 4098 |
| 44 | 4322 | 4222 | 4094 | 3826 |
| 65 | 4372 | 4124 | 3826 | 3577 |
| 90 | 4462 | 4213 | 3875 | 3478 |
| 110 | 4620 | 4252 | 3950 | 3552 |
| 130 | 4729 | 4372 | 4074 | 3726 |
| 145 | 4909 | 4521 | 4248 | 3950 |
| 165 | 5217 | 4719 | 4471 | 4173 |

*Table 3. The value of Lame parameter μ(c, T)*

| c, g/l | Lame parameter *μ*(*c*, *T*), kPa | | | |
|---|---|---|---|---|
| | *T* = 22°C | *T* = 31°C | *T* = 60°C | *T* = 88°C |
| 0 | 2427 | 2222 | 2107 | 2107 |
| 22 | 2043 | 1959 | 1915 | 1756 |
| 44 | 1852 | 1810 | 1754 | 1638 |
| 65 | 1874 | 1767 | 1638 | 1532 |
| 90 | 1912 | 1805 | 1660 | 1490 |
| 110 | 1980 | 1822 | 1692 | 1522 |
| 130 | 2026 | 1874 | 1745 | 1596 |
| 145 | 2104 | 1937 | 1820 | 1692 |
| 165 | 2235 | 2022 | 1915 | 1788 |

## 2. Results and discussion

The following dependences of the Young's deformation modulus and Lame parameters on the concentration of saline solutions and temperature were obtained as a result of experimental data statistical mathematical processing:

$$E(c,T) = (a_{18} \cdot c^2 + a_{17} \cdot c + a_{16}) \cdot T^2 + \\ +(a_{15} \cdot c^2 + a_{14} \cdot c + a_{13}) \cdot T + a_{12} \cdot c^2 + a_{11} \cdot c + a_{10} \quad (1)$$

where
$a_{18} = 1.179 \cdot 10^{-5}$, $a_{17} = -7.755 \cdot 10^{-4}$, $a_{16} = 0.024$, $a_{15} = -1.713 \cdot 10^{-3}$, $a_{14} = 0.138$, $a_{13} = -17.539$, $a_{12} = 0.198$, $a_{11} = -30.741$, $a_{10} = 6.546 \cdot 10^{3}$;

$$\lambda(c,T) = (a_{28} \cdot c^2 + a_{27} \cdot c + a_{26}) \cdot T^2 + \\ +(a_{25} \cdot c^2 + a_{24} \cdot c + a_{23}) \cdot T + a_{22} \cdot c^2 + a_{21} \cdot c + a_{20} \quad (2)$$

where
$a_{28} = 1.177 \cdot 10^{-5}$, $a_{27} = -9.23 \cdot 10^{-4}$, $a_{26} = 0.018$, $a_{25} = -1.558 \cdot 10^{-3}$, $a_{24} = 0.128$, $a_{23} = -14.343$, $a_{22} = 0.166$, $a_{21} = -25.543$, $a_{20} = 5.611 \cdot 10^{3}$;

$$\mu(c,T) = (a_{38} \cdot c^2 + a_{37} \cdot c + a_{36}) \cdot T^2 + \\ +(a_{35} \cdot c^2 + a_{34} \cdot c + a_{33}) \cdot T + a_{32} \cdot c^2 + a_{31} \cdot c + a_{30} \quad (3)$$

where
$a_{38} = 1.242 \cdot 10^{-5}$, $a_{37} = -1.983 \cdot 10^{-3}$, $a_{36} = 0.084$, $a_{35} = -1.3 \cdot 10^{-3}$, $a_{34} = 0.191$, $a_{33} = -12.748$, $a_{32} = 0.085$, $a_{31} = -13.816$, $a_{30} = 2.533 \cdot 10^{3}$.

The results of experimental data mathematical processing with the choice of the optimal scale have been shown in figures 1–3.

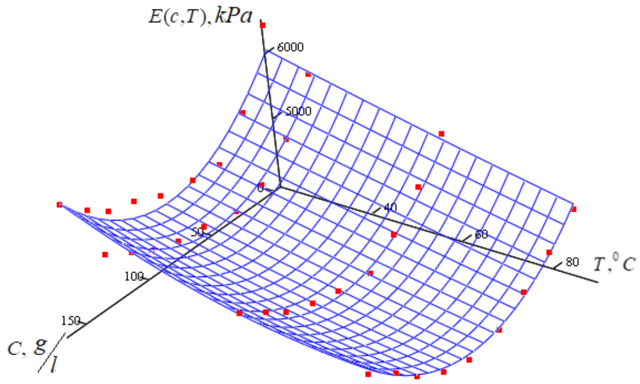


*Fig. 1. The graphic of Young's deformation modulus E(c, T), kPa on pollution concentration and temperature*

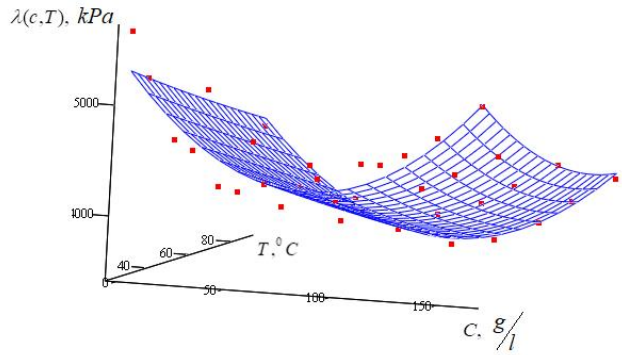


*Fig. 2. The graphic of Lame's parameter dependency λ(c, T), kPa on pollution concentration and temperature*

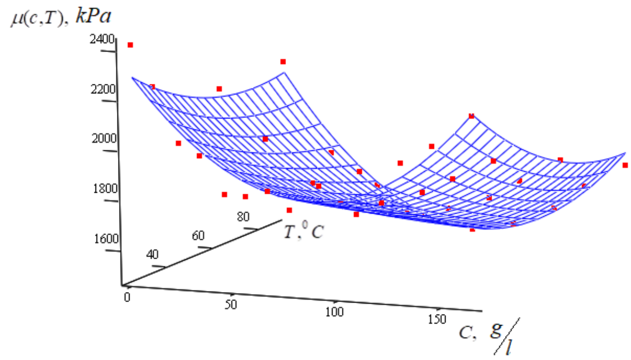


*Fig. 3. The graphic of Lame's parameter dependency μ(c, T), kPa on pollution concentration and temperature*

The established dependences of the Lame coefficients *λ*(*c*, *T*) and *μ*(*c*, *T*) on the filtration solution concentration and its temperature are in the area of scientific and practical interest. It can be further used in the creation of underground hydromechanics mathematical models and estimation of the stress-deformed state of soil environments. Accordingly, a new scientific field of these dependencies is emerging in new and updated mathematical models.

## 2.1. Mathematical model

Let us consider a one-dimensional problem for determining the vertical displacements of the soil layer based on the problem complexity. The soil mass thickness *l* has been given, in which the processes of heat transfer and mass transfer of contaminated substances take place (Fig. 4).

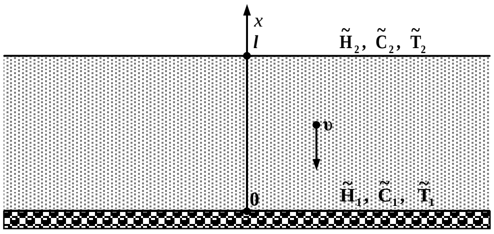


*Fig. 4. Soil mass scheme in one-dimensional case*

On Fig. 4. there is the scheme of soil massif in the one-dimensional case under the existence of pressures $\tilde{H}_2 > \tilde{H}_1$, the concentration of contaminated substances $\tilde{C}_2 > \tilde{C}_1$ and temperature $\tilde{T}_2 > \tilde{T}_1$ in the upper and lower ones of its limits.

The mathematical model of the one-dimensional problem of the stress-deformed state in the layer and soil mass thickness $l$ with the spread of contaminated substances and nonisothermal conditions in conventional symbols can be described in the following boundary value problem [16, 20, 22]:

$$(\lambda+2\mu)\frac{d^2U}{dx^2}+\frac{d(\lambda+2\mu)}{dx}\frac{dU}{dx}- -\left(\frac{d(\lambda+2\mu)}{dx}T+(\lambda+2\mu)\frac{\partial T}{\partial x}\right)\alpha_T = X \quad (4)$$

$$\varepsilon=\frac{dU}{dx},\ \sigma=E\left(\frac{dU}{dx}-\alpha_T\bar{T}\right),\ x\in(0,l), \quad (5)$$

$$L_1U(0)=0,\quad L_2U(l)=0, \quad (6)$$

and equations describing convective diffusion taking into account heat and mass transfer and convective heat and mass transfer with appropriate boundary conditions.

Here $x$ – vertical coordinate, $x\in(0;l)$; $U(x)$ – transfer in soil mass relative to the axis $Ox$; $X$ – volumetric force, which is determined with the formula $X=\gamma_{sb}+\frac{dp}{dx}$; $\lambda$, $\mu$ – Lame parameters; $c(x,t)$ – concentration of salt solution in soil mass; $\alpha_T$ – coefficient of linear heat expansion; $T(x,t)$ – temperature; $\gamma_{sb}$ – specific soil gravity in weighed state; $E$ – Young's module; $\varepsilon(x)$, $\sigma(x)$ – deformations and strains in the layer of soil mass relatively.

A finite-difference approximation of equations (4)–(6) by the finite difference method has been performed. The method of multiple calculations has been used to find the values of vertical displacements of the soil mass from equation (4).

The numerical experiments have been performed to establish the effect on the soil mass stress-deformed state of changes in the contaminated substance's temperature, in the presence of this factor, and in its absence.

For the case when the temperature of the pollutants corresponds to the environment, the dependences of the Lame parameters and the Yung's modulus on the concentration of the pollutants have been accepted based on the experimental data which are given in [15]:

$$\lambda(c)=a_3^2\cdot c^3+a_2^2\cdot c^2+a_1^2\cdot c+a_0^2 \quad (7)$$

where $a_3^2$ = -1798.96, $a_2^2$ = 4314.732, $a_1^2$ = -2615.37, $a_0^2$ = 2545.743;

$$\mu(c)=a_3^3\cdot c^3+a_2^3\cdot c^2+a_1^3\cdot c+a_0^3 \quad (8)$$

where $a_3^3$ = -1205.28, $a_2^3$ = 2880.321, $a_1^3$ = -1741.92, $a_0^3$ = 1696.324;

$$E(c)=a_3^4\cdot c^3+a_2^4\cdot c^2+a_1^4\cdot c+a_0^4 \quad (9)$$

where $a_3^4$ = -0.000393, $a_2^4$ = 0.1878866, $a_1^4$ = -22.70202, $a_0^4$ = 4410.552.

Numerous experiments have been carried out for the following input data:

$$l = 10\ \text{m},\ \gamma_{sb} = 1.1\cdot10^4\ {}^{\text{Pa}}/_{\text{m}},\ \alpha_T = 1\cdot10^{-6}\ {}^{1}/_{\text{deg}}$$

As soil environments can be affected by temperature, the effect of temperature and the concentration of contaminants on the values of vertical displacements must be taken into account.

The results of numerous experiments have been highlighted in Fig. 5.

This chart was received in our developed software complex. This software complex has been created as a web platform for online mathematical and computer modeling. It consists of the backend and frontend parts. The backend was written in C# programming language and used ASP.NET. Core technology, while the frontend uses Material framework and communicate with backend via specific API functions.

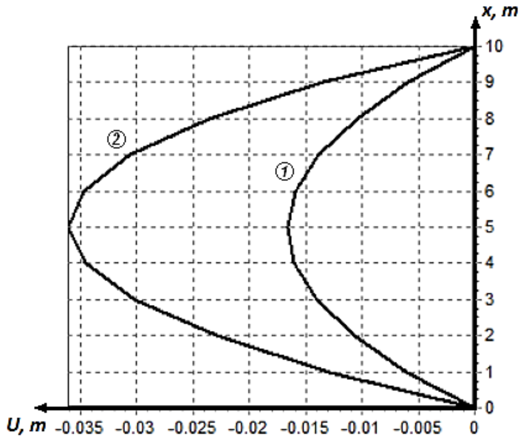


*Fig. 5. The graphics of transfer distribution in the conditions of heat mass transfer under the filtration of salt solutions in nonisothermal conditions for $t$ = 1440 days: 1 – under $\lambda=\lambda(c)$, $\mu=\mu(c)$; 2 – under $\lambda=\lambda(c,T)$, $\lambda=\lambda(c)$, $\mu=\mu(c,T)$*

Experimental studies have shown that considering the concentration of pollutants reduces the values of Lame parameters compared to not considering the concentration. Taking into account the dependencies of the Lame coefficients on the concentration of pollutants and temperature, as seen in Fig. 5, displacement values increase compared to displacement values considering only the dependence of the Lame coefficients on concentration.

## 3. Conclusion

The obtained dependences of the deformation modulus and Lame coefficients in the form of polynomials on the concentration of saline solutions and their temperature allowed to improve mathematical models of the stress-deformed state of the soil taking into account nonlinear deformation processes occurring in soil masses under the presence and filtration of saline solutions.

Incorporating the effect of temperature on soil environments, it's crucial to consider how both temperature and contaminant concentration influence vertical displacement values. This aspect is particularly important when modeling soil behavior under varied environmental conditions. Additionally, in scenarios where pollutant temperatures align with the ambient environment, understanding the relationship between pollutant concentration and soil properties like Lame parameters and Young's modulus becomes vital. These relationships are key to accurately predicting soil response and ensuring the integrity of structures built on or within these soils.

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## References

[1] Abdo A. M. A.: Utilizing a Simple Numerical Model in Discrete Element Analysis to Simulate Flow Time and Number Tests of Asphalt Mixes. Jou. Eng. Res. 11(2), 2017, 39 [https://doi.org/10.24200/tjer.vol11iss2pp39-49].
[2] Ait M'Barek S. et al.: Multi-Site Calibration and Validation of SWAT Model for Hydrologic Modeling and Soil Erosion Estimation: A Case Study in El Grou Watershed, Morocco. Ecol. Eng. Environ. Technol. 22(6), 2021, 45–52 [https://doi.org/10.12912/27197050/141593].
[3] Al-Abdul Wahhab H. I., Abdullah G. M. S.: Prediction of Permanent Deformation of Foamed and Emulsified Sulfur Asphalt Soils Mixes. Jou. Eng. Res. 15(2), 2018, 1 [https://doi.org/10.24200/tjer.vol13iss1pp1-21].
[4] Boyko I. P. et al.: Influence of hydrogeological conditions on the deformation of the fundamentals of existing foundations. Fundamentals and foundations 24, 1991, 23–30.
[5] Gerasimov I. et al.: Hydrodynamic features of the floating water outlet from a pumping station. Journal of Water and Land Development 48 (1) 2020, 162–171 [https://doi.org/10.24425/jwld.2021.136159].
[6] Hetnarski R. B.: Encyclopedia of thermal stresses. Springer Reference, Dordrecht 2014.
[7] Hutniczak A. et al.: The concept of reclamation in the life sciences to new environmental challenges. Inż. Ekolog. 20(4), 2019, 14–20 [https://doi.org/10.12912/23920629/113633].
[8] Jafari M. et al.: Dynamic approachs for system identification applied to deformation study of the dams. Acta Geod. Geophys. 50(2), 2015, 187–206 [https://doi.org/10.1007/s40328-014-0091-3].
[9] Jafari M.: Deformation modelling of structures enriched by inter-element continuity condition based on multi-sensor data fusion. Applied Mathematical Modelling 40(21-22), 2016, 9316–9326 [https://doi.org/10.1016/j.apm.2016.06.010].
[10] Kaliukh I. et al.: Decreasing Service Life of Buildings Under Regular Explosion Loads. Cybernetics and Systems Analysis 54(6), 2018, 948–956 [https://doi.org/10.1007/s10559-018-0098-9].
[11] Kaliukh I. et al.: Geotechnical Issues of Landslides in Ukraine: Simulation, Monitoring and Protection. Proceedings of China-Europe Conference on Geotechnical Engineering. Springer International Publishing, Cham 2018, 1466–1469.
[12] Klimov S. et al.: Limiting horizontal water filtration using drainage-screened modules. Journal of Water and Land Development 43(1), 2019, 90–95 [https://doi.org/10.2478/jwld-2019-0066].
[13] Kuzlo M. et al.: Deformations of Soil Massifs Under the Existence of Saline Solutions with Different Concentration and Temperature. Proceedings of the 2nd International Conference on Building Innovations. Springer International Publishing, Cham 2020, 123–131.
[14] Kuzlo M. T., Filatova I. A.: Investigation of the influence of the concentration of saline solutions on the deformation characteristics of soils. Bulletin National University of Water and Environmental Engineering, 31, 2006, 175–181.
[15] Kuzlo M. T.: Experimental and theoretical studies of soil masses' deformations under the action of human induced factors. NUWEE, Rivne 2019.
[16] Kuzlo M. T. et al.: Mathematical modelling of soil massif's deformations under its drainage. International Journal of Applied Mathematics 31(6), 2018 [https://doi.org/10.12732/ijam.v31i6.5].
[17] Kuzlo M. T. et al.: Experimental studies of saline solutions filtrations depending on their concentration and 114an dunder114. Automobile roads and road construction 107, 2020, 57–62.
[18] Methods of laboratory determination of durability and deformation characteristics. 2nd ed. (GOST 12248 – 96). State Committee of Ukraine for Urban Development and Architecture, Kyiv 01/04/1991.
[19] Sergeeva E. M. (ed): Soil Science. Moscow State University, Moscow 1983.
[20] Vlasyuk A. et al.: Mathematical Modelling of Spatial Deformation Process of Soil Massif with Free Surface. Advances in inteligent systems and computing IV, 1080, 2020, 107–120 [https://doi.org/10.1007/978-3-030-33695-0_9].
[21] Vlasyuk A. P. et al.: Computer modeling of heat and mass transfer effect on the three-dimensional stressed-strained state of soil massif. 18th International Multidisciplinary Scientific Geoconference SGEM, 18(1.2), 2018, 153–160 [https://doi.org/10.5593/sgem2018/1.2/S02.020].
[22] Vlasyuk A. P. et al.: Mathematic and computer modeling of cohesion effect forces on spatial deformation processes of soil massif. Math. Model. Comput. 7(1), 2020, 196–205 [https://doi.org/10.23939/mmc2020.01.196].
[23] Yamada Y., Ishihara K.: Anisotropic deformation characteristics of 114an dunder three dimensional stress conditions. Soils and Foundations 19(2), 1979, 79–94.

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