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FORECASTING THE STABILITY OF THE SOLID WASTE LANDFILL UNDER ITS CREATION

The modeling of the sedimentation of the solid domestic waste landfill with the use of the finite element method was carried out with the aim of predicting its stability in the creation and further use as a base of structures. His characteristic feature was accounting of geometrical and physicomechanical parameters of the ground and the soil basis. Using the C # programming language, software has been created to set the dependencies of the polygon sediment on the properties of the underlying soils and on the magnitude of the static load.

Key words: solid waste landfill, mathematical and computer modeling, precipitation, stability.

Introduction. Ukraine ranks first in the world in terms of the number of household garbage per capita. Under the landfills of solid waste landfill (SWL) and landfills occupy over 160 thousand hectares of land, and this figure is constantly increasing. In this connection, the issue of sustainability of polygons arises, they exist and are created, since improperly designed and constructed polygons is a source of catastrophic events that not only cost millions of dollars of losses but also lead to huge environmental pollution and even loss of life [8 -18].

Planning is especially important where construction of facilities in or near the landfill is expected. Depending on the planned use of the landfill, it is necessary to consider the following factors: the thickness of the covering layer, the underlying layer, the slope angle of the landfill and the disposal of waste, the degree of compaction, the use of additives and cement to strengthen the landfill, selective disposal of waste. When planning the use of the landfill, account should also be taken of the draft, the characteristics of the underlying soil, the availability and control of the infiltration and landfill gas collection systems and vegetation.

Evaluation of the stability of a landfill is often carried out by predicting the draft at the landfill. The precipitation is caused by many processes, in particular, biodegradation of organic matter, dissolution and oxidation of substances, reorientation of waste in the body of the landfill. Draft is divided into sediment caused by primary (instantaneous) and secondary (long-term) consolidation.

Models describing the sedimentation of the solid waste landfill can be divided into models based on soil mechanics, empirical models and models that take into account biodegradation [1 - 11]. The existing methods for estimating the draft have a number of shortcomings. In particular, a model that includes all the factors and parameters that affect sediment is missing and its development is an important issue. The most common model based on soil mechanics is a model of weak soil with creep Soft Soil Creep (SSC). [12 - 22].

A common feature of the developed models is that they take into account only the municipal solid waste, their behavior and properties, neglecting such an important component of the landfill, as the soil on which it is based. It is from the type of strength, geotechnical properties of this soil that the stability of the landfill depends, since they are the greatest load.

Experimental methods are costly and effective only for specific conditions. For example, the methods of reverse analysis are based on taking into account the properties of already destroyed landfills. In turn, laboratory analyzes do not allow to simulate the natural properties and processes occurring in landfills.

Therefore, studies of stress-deformed state of the soil mass under the landfill, affects the stability with the mechanical and geometrical properties of the landfill and the underlying ground, static and dynamic loads and filtration processes is actual scientific and practical challenge.

Goal and tasks. The aim of the work is to predict the sustainability of a solid waste landfill in its creation, taking into account physical, mechanical and geometric parameters. The task is to develop a spatial mathematical model and computer simulation of the consolidation process of the body of the solid waste landfill and the underlying soil.

Presentation of the main research material. Numerical modeling of the stressed-deformed state of the solid domestic waste landfill and ground base has been carried out to predict its stability during laying.

To account for the liquid phase of the waste and the underlying soil, Darcy's law is used in the form of the equation of the balance of forces:

$$-\nabla P - \frac{\eta}{K}\vec{u} + \rho\vec{f} = 0, \quad (1)$$

where P is external pressure; ρ is the density; η is the dynamic viscosity; g is acceleration of gravity; $\vec{u}$ is the filtration rate; $\vec{f}$ is the field of external forces; $K = \eta k / \rho g$ is the permeability coefficient characterizing the porous medium's ability to pass fluid.

The complete system of equations for the filtration of an incompressible fluid also includes the incompressibility equations:

$$div\,\vec{u} = 0, \quad (2)$$

and the continuity equation:

$$div\,\rho\vec{u} = -\rho m, \quad (3)$$

where m is the porosity of the soil.

It is assumed that the compressibility of the skeleton and the pore fluid is small, which leads to a linear dependence of soil porosity on pressure.

The covering and underlying layers of the soil were described by the Mohr-Coulomb model, in which the complete yield condition consists of six yield surfaces and six plastic potential functions.

The body of the polygon is modeled by a weak soil, taking creep into account, using the Soft Soil Creep (SSC) model [23 – 25]. At present, this model most fully describes such properties of weak soil as stress-dependent stiffness, as well as secondary compression with allowance for creep, in addition, it takes into account both the physical and geometric non-linearity of the process of soil deformation.

Full volumetric deformation ε_v, caused by the growth of effective stresses from the initial value p_0' up to p' for a period of time t_c+t', consists of elastic ε_v^e and viscous-plastic ε_v^{vp} components. Viscous-plastic component is the total of deformation during consolidation ${\varepsilon_v^{vp}}_c$ and after consolidation ${\varepsilon_v^{vp}}_{ac}$. The relationship between the deformations is expressed in the following form:

$$\varepsilon_v = \varepsilon_v^e + {\varepsilon_v^{vp}}_c + {\varepsilon_v^{vp}}_{ac}; \quad (4)$$

$$\varepsilon_v^e = \kappa^* \ln\left(\frac{p'}{p_0'}\right); \quad (5)$$

$${\varepsilon_v^{vp}}_c = (\lambda^* - \kappa^*) \ln\left(\frac{p_{pc}'}{p_0'}\right); \quad (6)$$

$${\varepsilon_v^{vp}}_{ac} = \mu^* \ln\left(\frac{\tau_c + t'}{\tau_c}\right), \quad (7)$$

where μ^* is the modified coefficient of creep; τ_c is the time of consolidation, that depends on the geometry of the sample under consideration; t' is the time elapsed since the beginning of the loading of the landfill; κ^* is the modified coefficient of swelling; λ^* is the modified coefficient of compression; t_c is the time of completion of primary consolidation; p_0' is the initial effective stress; p' is the effective stress; p_{pc}' is the effective pre-consolidation stress.

The equation for determining the free surface of the filtration flow in the calculation of unstable filtration in the body of a polygon with allowance for infiltration should satisfy the following boundary conditions: 1) the pressure is equal to atmospheric pressure; 2) the normal velocity component on the surface is absent. At the boundaries between the layers of the polygon and the ground base, the conditions for the equality of the normal stress components and the rate of filtration are satisfied.

The initial conditions are: the filtration rate in the layers of the polygon and the underlying soil is zero; Atmospheric pressure acts on the surface, each layer of waste and ground has its own initial physical and mechanical properties, initial geometric parameters of the polygon are specified.

To calculate the coefficients of swelling, compression, consolidation, program software (PS) was created using the C # programming language. As a result of the numerical calculation, strain dependencies were obtained from the stresses under the static load of the body of the solid waste landfill. The parameters of the underlying soils and wastes are presented in Table. 1 and 2 respectively. Layer #1 is the latest layer, layer #10 is the first that lies in the foundation of the polygon

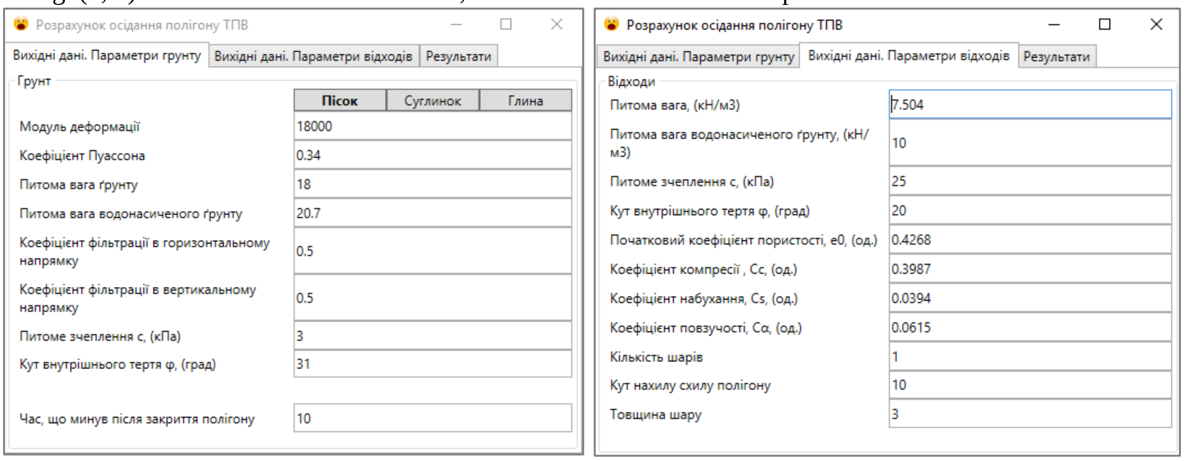
Table 1 - Physical and mechanical parameters of soils

Parameter	Soil		
	Sand	Loam	Clay
Modulus of deformation E_{ref},(kN/m^3)	18000	10000	9000
Poisson's Ratio ν, (unit)	0,34	0,36	0,37
Specific gravity of soil γ_{unsat}, (kN/m^3)	18,0	13	19,0
Specific gravity of water-saturated soil γ_{sat}, (kN/m^3)	20,7	14,6	21,8
Filtration coefficient in horizontal direction k_x, (unit)	0,5	0,006	0,004
Filtration coefficient in vertical direction k_y, (unit)	0,5	0,006	0,004
Modulus of deformation E , (MPa)	50	33	28
Specific cohesion c, (kPa)	3	34	81
The angle of internal friction φ, (degree)	31	14	13

Table 2 - Physical and mechanical parameters of the waste products

Parameter	Value
Specific gravity of soil γ_{unsat}, (kN/m^3)	7,504
Specific gravity of water-saturated soil γ_{sat}, (kN/m^3)	10,0
Specific cohesion c, (kPa)	25
The angle of internal friction φ, (degree)	20
The initial coefficient of porosity, e_0, (unit)	0,4268
Coefficient of compression, C_C, (unit)	0,3987
Swelling coefficient, C_S, (unit)	0,0394
The coefficient of creep, $C\alpha$, (unit):	
Layer #1	0,0615
Layer #2	0,0474
Layer #3	0,0448
Layer #4	0,0429
Layer #5	0,0414
Layer #6	0,0402
Layer #7	0,0391
Layer #8	0,0382
Layer #9	0,0374
Layer #10	0,0367

In Fig. (1, a) shows the main initial screen of the software, where data are entered for further calculation in accordance with the soil parameters. Parameters for sand, loam and clay are set separately in their respective tab. In Fig. (1, b) is a tab of the software screen, where data is entered for the parameters of the waste.



(a) (b)

Figure 1 – Background data: (a) soil parameters, (b) waste parameters

The results of calculating the coefficients of swelling, compression, consolidation, and the relationship between deformations, depending on the type of soil, are shown in Fig. 2 (a, b, c).

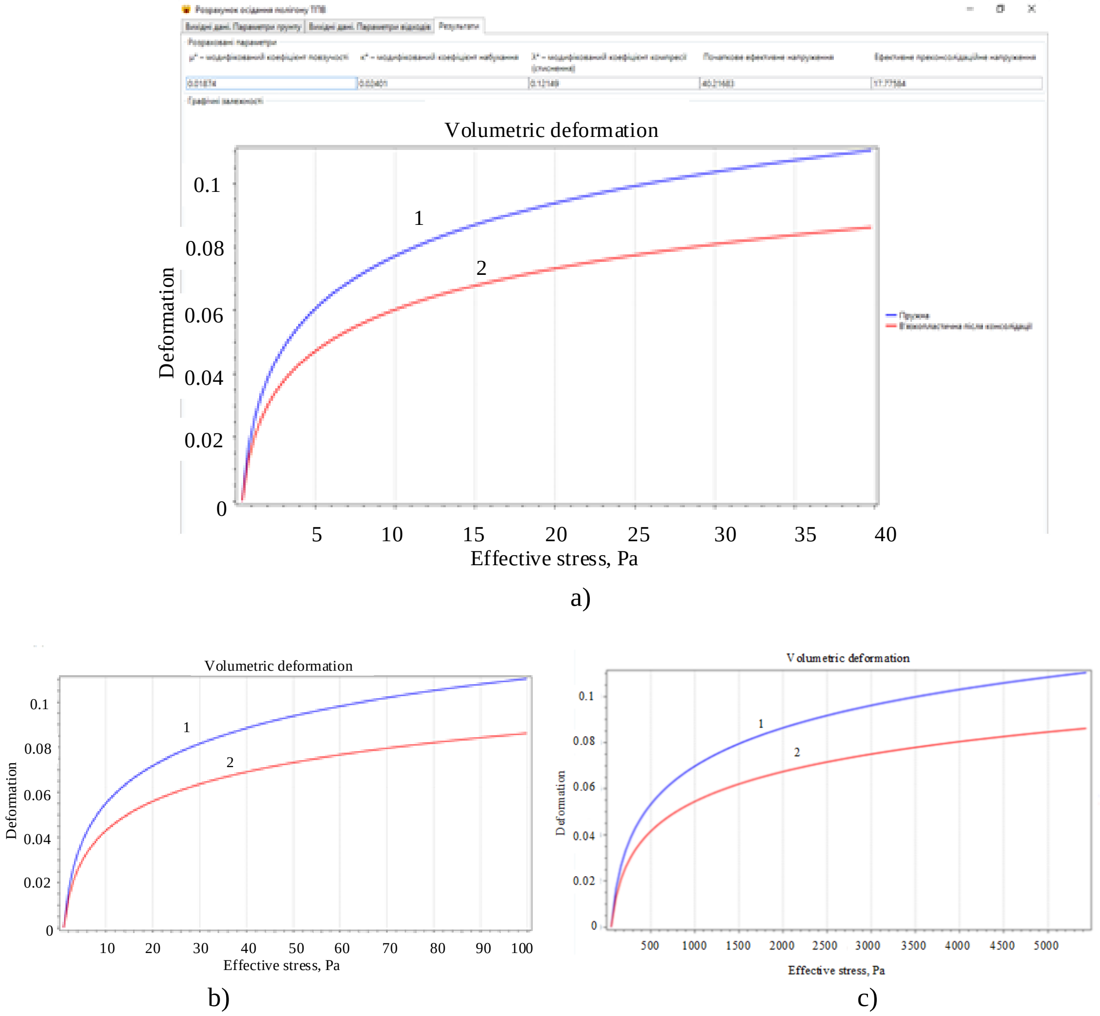


Figure 2 – The result of calculations for the soil: (a) – sand, (b) – loam, (c) – clay; 1 – spring strain, 2– viscous-plastic after consolidation

From the analysis of Fig. 2 it can be observed that there is less sediment of the landfill when the underlying soils are clay, and the most sediment is with sand. For example, an elastic complete deformation of 0.12 is achieved in clay with an input of 5000 Pa, in loam - 100 Pa, in sand - 40 Pa. From which it can be concluded that the underlying soil has a big influence on the sedimentation of the landfill.For the numerical solution of the problem the finite elements method was used. The estimated area was divided into 265 finite elements.

We investigated the influence of underlying soil (clay, sand or loam) foundation on settlement. The landfill for which the simulation was conducted consists of ten layers of the waste, the thickness of each layer is 3 m. The angle of inclination of the slope of the landfill was 75°.

The results of numerical calculations are shown in Fig. 3. The vertical deformations of the polygon with the sandy bottom of the base are shown in Fig. 3. It can be seen from the analysis of the figure that the greatest deformation is observed in the upper layers of the polygon and is 4.95 m, and the smallest in the layer lying at the base of the polygon (0.42 m). This is because the lower layers of the polygon are condensed more than the top layers. The deformations of the foundation soil are the largest at the bottom corners of the polygon body (0.041 m), and the smallest - in the center (0.0101 m), since the corners are stress concentrators, in turn causes an increase in deformations.

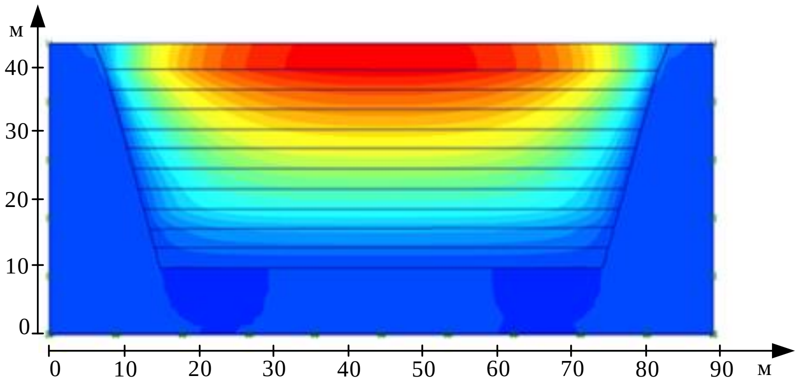


Figure 3 - Vertical deformation of the landfill with sandy bottom soil

From the results of calculations it is established that under the same conditions of the landfill, the underlying soil layer exerts a considerable influence on the sediment value: the denser and less porous the soil, the less the sediment. In particular, if the soil base is clay, a sludge is 23% less than sand, and 14% less than with loam as a base.

Conclusion. Thus, it was developed spatial mathematical model of process of consolidation of solid waste landfill in which for the first time it is offered to consider the spreading soil as it is one of major factors when forming draft. The software in a programming language C # for calculation of coefficients of swelling, a compression, consolidation and numerical calculation of dependence of deformations on tension at static loading of a body of solid waste landfill was created. The effective method of calculation of the intense deformed state combined the natural and technogenic environment which allows to predict its stability during his creation and reuse as a basis of constructions of different function is developed.

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ПРОГНОЗУВАННЯ СТІЙКОСТІ ПОЛІГОНУ ТВЕРДИХ ПОБУТОВИХ ВІДХОДІВ ПРИ ЙОГО СТВОРЕННІ

Проведено моделювання осадки полігону твердих побутових відходів із застосуванням методу скінчених елементів з метою прогнозування його стійкості при створенні і подальшому використанні в якості основи споруд. Характерною його особливістю було врахування геометричних та фізико-механічних параметрів полігону та ґрунтової основи. За допомогою мови програмування C# створено програмне забезпечення для встановлення залежностей осадки полігону від властивостей підстилаючих ґрунтів та від величини статичного привантаження.

Ключові слова: полігон твердих побутових відходів, математичне та комп'ютерне моделювання, осадки, стійкість.

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