EFFECT OF DEEP EXCAVATIONS WITH FILLER CONSTRUCTIONS ON THE GROUNDWATER FILTRATION PROCESSES

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Summary. The influence of deep pits with filler walling on the filtration of groundwater has been considered also approximate numerical methods of mathematical modeling and solving of nonlinear equations of groundwater filtration in built-up areas in finding deep pits.

Keywords: filler walling constructions, deep excavations, groundwater filtration

INTRODUCTION

Possible effects of flooding and suffosion in urban environment requires a clear knowledge of the dynamics of the forecast level of groundwater and identification of methods of control levels and gradients by applying different designs drainages. Regulation of groundwater level and changes in its levels and gradients during the construction and maintenance of buildings and structures influence the choice: the type of foundations, their sizes, depth of location, types of drainage and water-protection measures and others. At rising ground water level can vary the strength and deformation properties of clay soil beddings, or swelling occur subsidence of soil, increase the degree of frosty loop and others. When lowering the groundwater level may occur as additional compaction of clay and sandy soils. Positioning of ground water level and the ability to change soil moisture during construction works take the results of geological surveys and forecasts are based on special investigationss or calculations [6, 8].

PROBLEM STATEMENT

Analysis of water filtration in conditions of intensive technogenic impact indicates that the suffosion processes significantly influence the formation of porous structure, filtration and mechanical properties of soils [11]. Thus, sustainable development of suffosion processes accompanied by weighing, transfer and leaching of fine particles from the soil skeleton can lead to a significant increase soil permeability and the loss of its strength and stability. Such phenomena lead to subsidence and even failures of the land within the existing building, which can cause accidents and even complete destruction of houses and various engineering structures with severe environmental consequences [2, 7].

Mathematical models and calculation methods in view of change properties of soil and artificial porous materials due to suffosion by ecological forecasting in recent years received significant development in the works [10, 16].

However, filtration modeling methods built-up areas in residential areas of cities in zones of deep foundation ditches influence in view of change properties of soils due to suffosion and colmatation processes have been developed not sufficiently.

BASIC PART

To establish the influence of deep foundation ditches on the dynamics of groundwater and the possibility of suffosion processes development some mathematical models have been considered.

The basis for developing mathematical models of filtration of groundwater in built-up areas within the influence of deep foundation ditches, taking into account various factors and processes of suffosion is the equation of motion and continuity of fluid, convective diffusion, suspended particles and mass transfer, and experimental ratios that express the law of resistance (in the case of linear filtering - a Darcy's law) and filtration coefficient dependence on the concentration of sediment [5, 20].

In the case of linear filtering one-component fluids, these equations can be written in the following general form:

$$\mu_e \frac{\partial H}{\partial t} = div\left(k(\sigma) grad\ \ H\right), \tag{1}$$

$$\frac{\partial (nC)}{\partial t} = div\left(D\ gradC - \overline{V}C\right) - \frac{\partial \sigma}{\partial t}, \tag{2}$$

$$\overline{V} = -k(\sigma)\ gradH;\quad \frac{\partial \sigma}{\partial t} = f\left(C, \sigma, C_{\max}, \sigma_{\max}, \eta_1 \ldots \eta_N\right),$$

where: t is time, $H = H(x, y, z, t)$ is hydrodynamic pressure, $C = C(x, y, z, t)$ is mass concentration of fine suspended impurities, $\sigma = \sigma(x, y, z, t)$ is mass concentration of sediment, $\overline{V}$ is vector filtration rate, μ_e is coefficient of elastic capacity of the layer, n is soil porosity, $k(\sigma)$ is filtration coefficient, which depends on the concentration of sediment, $C_{\max}, \sigma_{\max}$ are maximum concentrations of contaminants in pore solution and solid phase, D is convective diffusion coefficient, $\eta_1, \ldots \eta_N$ are experimental factors.

Kinetic equation (2) describes different cases of mass transfer of suspended impurities from the material porous medium, and the literature has indicated that to describe the physical (mechanical) soil suffosion and soil colmatation commonly used are given below the characteristic equation:

1. The equation of sorption kinetics of irreversible physical:

$$\frac{\partial \sigma}{\partial t} = \alpha C\ . \tag{3}$$

Recorded the equation used to describe the initial period of mass transfer in porous media at low concentration of suspended impurities, low filtration rate and high sorption capacity of porous medium.

2. The equation of not equilibrium reversible physical adsorption and desorption (colmatation and suffosion). The linear equation:

$$\frac{\partial \sigma}{\partial t} = \alpha C - \beta \sigma\ . \tag{4}$$

Equation (3-4) used in the research in the solution of equations of mass transfer and mass exchange analytical methods [9].

The linear equation:

$$\frac{\partial\sigma}{\partial t}=\alpha^{*}(\sigma_{max}-\sigma)C-\beta\sigma\,, \tag{5}$$

approximates more closely the experimental results. In the equations (3–5) α, α* are velocity of particles sticking coefficients, β is coefficient of velocity separation. Linearization of equation (5) leads it to (4), if $\alpha=\alpha^{*}(\sigma_{max}-\sigma_s)$, where σ_s is averaged concentration of sediment. Equations (4) and (5) are widely used in modelling of the mechanical colmatation and suffosion in hydraulic engineering and melioration.

In general, the filtering process and the migration of suspended pollutants and fine particles of soil in zones of deep foundation ditches have a complex spatial structure, which complicates their modeling on modern PCs. So to solve of applied engineering problems, one-dimensional or two-dimensional mathematical models are often used.

Planned mathematical models of filtration and mass transfer are approximate and obtained by integrating the full equations (1-2) and vertically averaged unknown functions and coefficients. It can be obtained directly from the application of continuity equation and balance equations for filtration.

Mathematical model of the planned filtration and convective diffusion-weighted pollution and small particles, considering the processes of physical adsorption (colmatation) and desorption (suffosion) based on the above principles in view of kinetic equation (5). This model describes the change of groundwater level, the dynamics of concentration of suspended pollutants and fine particles in the soil pore space when using the exponential dependence of filtration of sediment concentration of salts in the solid phase:

$$\frac{\partial\theta}{\partial H}\frac{\partial H}{\partial t}=\frac{\partial}{\partial x}\left(k_x\frac{\partial H}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_y\frac{\partial H}{\partial y}\right)+Q,\quad H=\psi-y \tag{6}$$

$$\frac{\partial(\theta C)}{\partial t}=\frac{\partial}{\partial x}\left(D_x\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_y\frac{\partial C}{\partial y}\right)-V_x\frac{\partial C}{\partial x}-V_y\frac{\partial C}{\partial y}-\frac{\partial\sigma}{\partial t}, \tag{7}$$

$$V_x=-k(\sigma)\frac{\partial H}{\partial x},\quad V_y=-k(\sigma)\frac{\partial H}{\partial y}$$

$$\frac{\partial\sigma}{\partial t}=f(C,\sigma,C_{max},\sigma_{max},\eta_1\ldots\eta_N) \tag{8}$$

$$\mu\frac{\partial h}{\partial t}=\frac{\partial}{\partial x}\left(k(\sigma)(h-m)\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(k(\sigma)(h-m)\frac{\partial h}{\partial y}\right)+\varepsilon \tag{9}$$

$$\left(n_0-\frac{\sigma}{\rho_{sed}}\right)\frac{\partial C}{\partial t}=\frac{\partial}{\partial x}\left(D\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(D\frac{\partial C}{\partial y}\right)-V_x\frac{\partial C}{\partial x}-V_y\frac{\partial C}{\partial y}-\frac{\partial\sigma}{\partial t}+\frac{\varepsilon}{h}(C_p-C), \tag{10}$$

$$k(\sigma) = k_0 \exp\left(-\gamma \frac{\sigma}{\sigma_{\max}}\right), \qquad (11)$$

$$V_x = -k(\sigma)\frac{\partial h}{\partial x}, \quad V_y = -k(\sigma)\frac{\partial h}{\partial y} \quad .$$

where: x,y are plan coordinates; $h = h(x, y, t)$ is ordinate free surface flow filtration; μ is lack of saturation coefficient (water return), k_0 is filtration coefficient of pure soil, $k = k(\sigma(x, y, t))$ is filtration coefficient, which depends on the concentration of sediment; γ is experimental parameter; n_0 is porosity of non-colmatation soil; $D = D_m + \lambda|V|$; D_m is molecular diffusion coefficient; λ is coefficient of hydro dispersion; V_x , V_y are filtration velocity vectors; $\sigma_{\max}$ is concentration of pore water saturation limit of fine particle pollution and shallow soil; ρ_{sol} is density of sediment; ε is power intensity of infiltration; C_p is concentration of suspended impurities in water infiltration [3, 4].

For simple determination of unknown functions using equations (9-10) set the initial and boundary conditions for typical cases of filtration and mass transfer [1].

Consideration of pile fields damming effect that reinforce the filler walls of foundation ditches, Carried out by the method of additional filtration resistance within boundaries, or a reduction of the soil filtration coefficient in the relevant areas.

In addition with the planned task considered above filtering review mathematical models of flat-vertical filtering in homogeneous and inhomogeneous-layered soil, taking into account changes in filtration coefficient of soil compaction in areas of significant groundwater depression.

Solving nonlinear equations discussed above filtration, mass transfer and mass exchange for practical problems obtained on the basis of approximate numerical methods

To solve the equations written above appropriateapply the the method of finite differences using an implicit non-iteration locally - one-dimensionalpatterns (ineach estimated time coefficients difference equations , which depend on unknown functions are evaluated on their values in previous time). Each settlement interval of time is divided into two half a step, which in turn are solved one-dimensional analogues of equations (9) and (10) using the difference approximation of boundary conditions. For example, equation (9) toward the axis 0X difference approximation in a following form:

$$\mu\left(\frac{h_{i,j}^{k+0,5} - h_{i,j}^{k}}{\Delta t_k/2}\right) = \frac{1}{\Delta x_c}\left(A_{i,j+0.5}\frac{h_{i,j+1}^{k+0,5} - h_{i,j}^{k+0,5}}{\Delta x_{j+1}} - A_{i,j-0.5}\frac{h_{i,j}^{k+0,5} - h_{i,j-1}^{k+0,5}}{\Delta x_j}\right). \qquad (12)$$

Similarly, finite difference equations are written in the direction of the axis 0Y.

The solution of this equation system obtained by the Damaged method. After half a step of the second time calculated filtration rate, and then solved the equation of convective diffusion, and to approximate convective plugin widespread use in numerical solution of hydrodynamics scheme of differences against flow.

$$\left(n_0-\frac{\sigma_{i,j}}{\rho_{sed}}\right)\left(\frac{C_{i,j}^{k+0,5}-C_{i,j}^{k}}{\Delta t_k/2}\right)=\frac{1}{\Delta x_c}\left(D_{i,j+0.5}\frac{C_{i,j+1}^{k+0,5}-C_{i,j}^{k+0,5}}{\Delta x_{j+1}}-D_{i,j-0.5}\frac{C_{i,j}^{k+0,5}-C_{i,j-1}^{k+0,5}}{\Delta x_j}\right)-$$
$$V_{x,i,j}\begin{Bmatrix}\left(C_{i,j}^{k+0,5}-C_{i,j-1}^{k+0,5}/\Delta x_j\right), & V_{x,i,j}>0\\ \left(C_{i,j+1}^{k+0,5}-C_{i,j}^{k+0,5}/\Delta x_{j+1}\right), & V_{x,i,j}\le 0\end{Bmatrix}-\alpha^{*}\left(\sigma_{\max}-\sigma_{i,j}^{k}\right)C_{i,j}^{r}+\beta\sigma_{i,j}^{k} \quad . \qquad (13)$$

In the technique usable notion of path filtering under which believe array boundary where the flow moves filtration.

Implementation of the numerical solution algorithm of the problem has been done on PC-based computer program. Solving the problem on a PC made after determining the boundaries through which water enters the scheme limits outflow of water from the scheme, which borders on the estimated diameter cut out of the array and establish the boundary around the free surface (curve depression). In the numerical scheme, these limits have to be shown locked chain segments. This is the path filtering.

As an example, the impact foundation pit on the dynamics of groundwater in the area of building a house has been considered [12-16]. The view of the foundation pit wall fastening is in Figure 1.

Absolute ground marks within the calculation profile ranged from 159.0 to 188.70 at the top of the slope. In the geological structure of the slope to the depths explored compiled Quaternary, Neogene and Paleogene sediments, which are distributed based on an analysis of 11 geological item. Ground water flow into the construction foundation pit had power 3 - 5 m and was located on the clay within the freshwater and loess loams.

Fig.1. The filler walls fastening for foundation pit at construction site

Fastening of foundation pit wall mounting piles, which partitions the flow of groundwater, creates barazhnyy effect, increases the level and magnitude of groundwater flow filtration gradients near the walls of the foundation pit. In Fig.2 shows the solution of equation (6), which made via the PC in finding foundation pit with permeable wall mount enclosure.

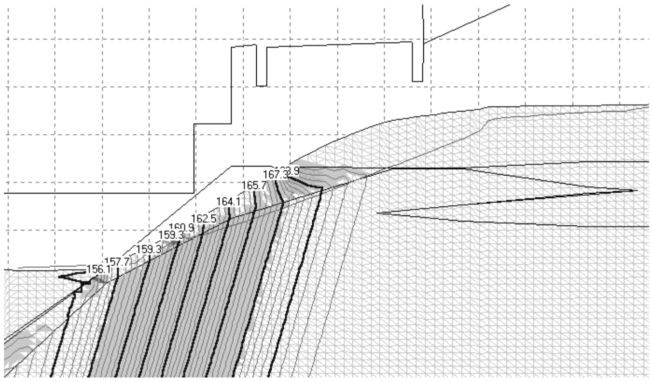

Fig.2. Solving the profile filtering problem attached to water penetrating foundation pit walls and their influence on the flow of groundwater within the area of house building

In reality bored piles, as shown in Fig.2, are water impermeable. For these conditions, groundwater level rises significantly before the pits, and within the structures that filler pit structures, significantly increasing gradient flow filtration. Solving the problem of filtration for such conditions is shown in Figure 3.

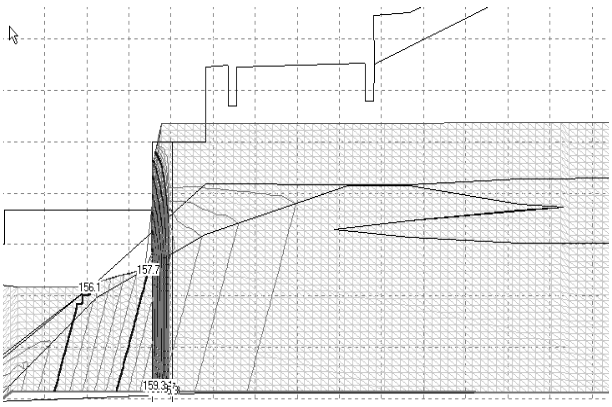

Fig.3. Solving the problem of filtering profile to establish the impact the pit walls to the flow of groundwater within the area of building a house

Ground level after installation of filler walls mounting to pits up to 2 - 2,5 m, and by the pit fell to 1.5 -1.8 m. In the area of flow filtration output in the excavation trenches between piles flow filtration gradient increased rapidly.

CONCLUSION

Mathematical modeling of groundwater level in built-up areas in finding deep foundation ditches requires solving nonlinear equations of filtering, which can be obtained by approximate numerical methods [17-19]. In general, the filtering process and the migration of suspended particles in the soil zones, deep foundation ditches have a complex spatial structure, which greatly complicates their modelling. So to solve applied engineering problems is recommended to use one-dimensional or two-dimensional mathematical models and carry out full scale laboratory and experimental studies to determine the model parameters.

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ВЛИЯНИЕ ГЛУБОКИХ КОТЛОВАНОВ С ОГРАЖДАЮЩИМИ КОНСТРУКЦИЯМИ НА ПРОЦЕССЫ ФИЛЬТРАЦИИ ГРУНТОВЫХ ВОД

Аннотация. Рассматривается влияние глубоких котлованов с ограждающими конструкциями на процессы фильтрации грунтовых вод и приближенные численные методы математического моделирования и решения нелинейных уравнений фильтрации грунтовых вод на застроенных территориях при устройстве глубоких котлованов.

Ключевые слова: ограждающие конструкции, глубокие котлованы, фильтрация грунтових вод.