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Taking into Account the Elastic-Plastic Properties of Clay Soils in Engineering Calculations

Mukim Mukhtarovich Yakubov
Cand. tech. Sci., Associate Professor, Samarkand State Institute of Architecture and Civil Engineering, Samarkand. muqumjon.yakubov@mail.ru
Faizulla Abdullaevich Ikramov
Cand. tech. Sciences., Acting prof., Samarkand State Institute of Architecture and Civil Engineering, Samarkand
incpekciya@yandex.ru

Abstract: In the proposed work, a nonlinear dependence is given, which makes it possible to determine the limiting value of the forces on the pile at a given value of the permissible settlement outside the proportionality limits, and also shows the real possibility of using nonlinear properties of deformation of clay soils in engineering calculations.

Key words: loading path, shear stresses, settlement, nonlinear properties, piles, vertical displacements, angular deformation.

Introduction. The constitutive equations (1) satisfactorily describe the deformation of the hardening clay soil from stresses [1,4]. $\tau = \frac{q^* \gamma^*}{D} \ell n \left\{ 1 + \frac{G^e \cdot D \cdot \gamma}{q^* \gamma^*} \right\}$ (1)

where $D = 1 - K_\sigma \left(tg\varphi + \beta_\sigma \right) - \beta_\tau$ (2)

K_σ – loading path parameter;

It can be seen that, all other things being equal, i.e. permanence $G^e, tg\varphi, \beta_\sigma, \beta_\tau$ the limit value of the shear stresses depends on the loading path K_σ .

The above constitutive equations (1) can be used in engineering calculations in different ways, depending on the complexity of the stressed - deformed state of the soil mass, affecting structures and structures [3].

In most cases, with such an interaction in the soil mass, a complex and inhomogeneous (in coordinates) stress-strain state arises and the use of nonlinear relationships between stresses and deformations, as a rule, leads to a numerical method for solving problems using a computer. At the same time, problems are often encountered when a relatively homogeneous stress state arises in a soil mass interacting with engineering structures, which is practically independent of the mechanical properties of clay soils.

Methods and materials. In such problems, the transition from the stress state to displacements is easily carried out by integrating the deformation functions associated with the known stress state of the rock mass directly. Such tasks include the displacement of a soil layer of limited thickness in the foundations of gravity hydraulic structures, on a landslide slope and around long piles [3].

Let's consider the problem. Let a long pile be immersed in soft clay soils. It is required to determine the limiting value of the load on the pile if the mechanical properties of clay soil, including plastic ones, are known [2].

In this case, the calculation scheme for the development of settlement can be represented in the form (Fig. 1.)

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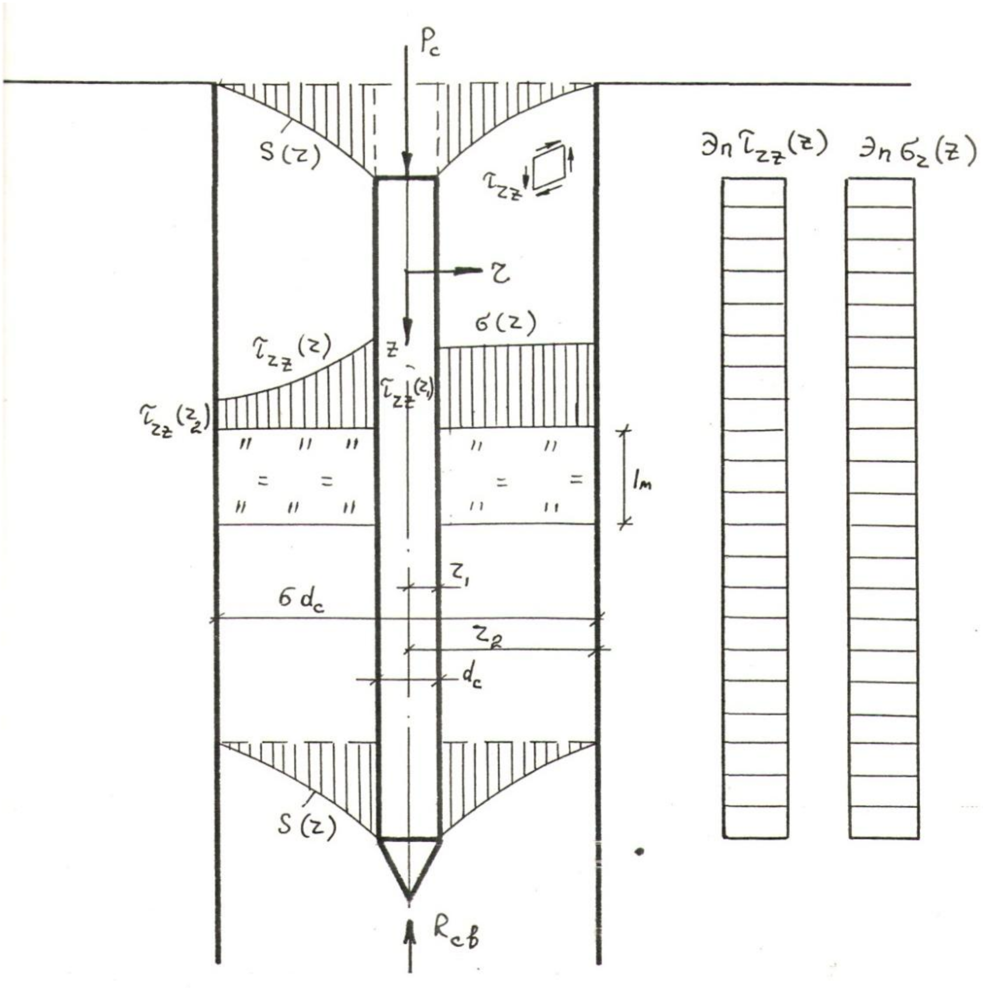

Fig. 1. Design scheme for determining the vertical movement of a single long pile in the ground.

It can be seen that the vertical displacements of the soil around the piles attenuate to a distance $3d_c$, which is consistent with numerous observations. Shear stresses also decrease with the distance from the pile to the zone of influence according to a certain law.

Let us first determine the shear stresses on the pile surface, i.e. we have

$$\tau_{rz}(r_1) = \frac{P-R}{2\pi r_{.1} \cdot \ell} \quad (3)$$

At a distance $r = r_2$ these voltages will be equal $\tau_{rz}(r_2) = \frac{P-R}{2\pi r_2 \cdot \ell}$ (4)

Vertical displacements of the soil are associated with angular deformations by known dependencies

$$\gamma_{rz} = \frac{dw}{dr} + \frac{du}{dz} \quad (5)$$

assuming that $\frac{du}{dz} = 0$, those. we have

$$dw = \gamma_{rz}(r)dr \qquad (6)$$

Substituting dependence (1) here, we can determine the displacement of the pile by the formula

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$$w=\int_{r_1}^{r_2}\gamma_{rz}\left[\tau_{rz}(r)\right]dz \quad (7)$$

We transform formula (1) to the form

$$\tau_{rz}=\frac{g^{*}\cdot\gamma^{*}{}_{rz}}{D}\,\ell n\left\{1+\frac{G^{e}\cdot D}{g^{*}\cdot\gamma^{*}_{rz}}\cdot\gamma_{rz}\right\} \quad (8)$$

Results. Substituting here the value (τ_{rz}) determined by formulas (3,4,6), and then in (7), after integration we obtain the dependence between the magnitude of displacement, assuming that $\tau_{r(z)}(r)=const$ get

$$w=\int_{r_1}^{r_2}\gamma_{rz}(r)dz=\frac{e^{A\tau_{rz}}-1}{AG^{e}}\left(r_2-r_1\right) \quad (9)$$

where $A=\frac{D}{g^{*}\gamma^{*}_{rz}}\cdot$ (10)

Conclusion. As you can see, this dependence is nonlinear and allows you to determine the limiting value of the force on the pile P_c^{*} as you can see, this dependence is nonlinear and allows you to determine the limiting value of the force on the pile).

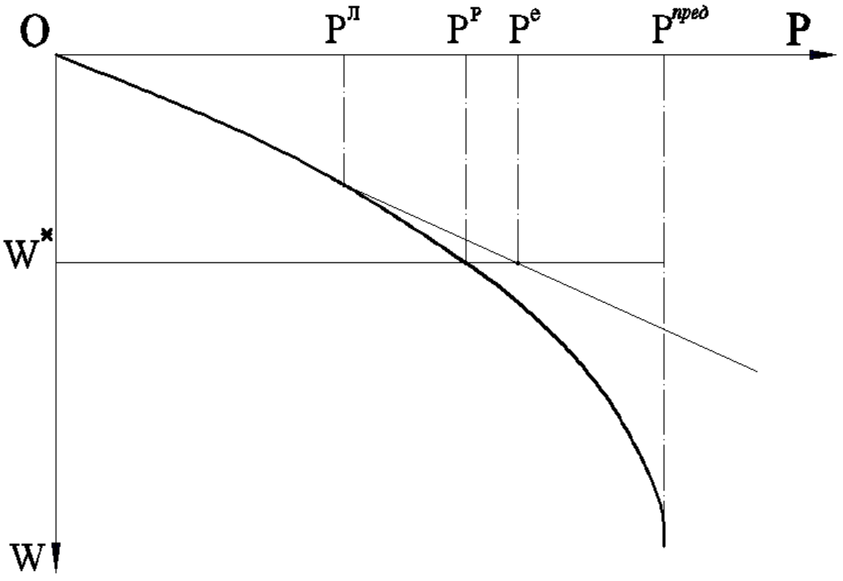

Fig. 2. Scheme for calculating the ultimate straight bearing capacity of a pile taking into account the nonlinear properties of clay soil for a given value of vertical displacement.

W^{*} - specified amount of vertical movement;

$P^{Л}$ – limit value of direct proportionality.

Thus, on the basis of the considered problem, the real possibility of using the nonlinear properties of deformation of clay soils in engineering problems is shown. The effectiveness of solving engineering problems in this formulation is obvious, since this makes it possible to use the reserves of the bearing capacity of the soil massif when interacting with structures.

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