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BENDING OF A PILE FOUNDATION IN THE PRESENCE OF ZONES OF ELASTIC AND ELASTIC-PLASTIC LAW OF INTERACTION WITH THE SOIL ENVIRONMENT

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Abstract
Improving the quality and efficiency of construction on subsidence soils largely depends on the correct assessment of their properties and the choice of foundations. It is traditionally believed that when constructing on weak and subsidence soils, priority belongs to pile foundations, which are of particular importance in the construction of underground and buried structures in urban conditions, leading to the development of additional settlements of the surrounding buildings located in the zone of influence of new construction. The article proposes a method for calculating the effect of horizontal force on the grillage of a pile (single column) buried in the soil and interacting with it according to the elastic-plastic law. Bedding coefficient

Keywords: Subsidence, deepening, settlement, plastic law, development, intensity.

Introduction

In the works [1-4] it is established that the value of soil resistance along the lateral surface of the bored pile in hard clay soils is influenced by both the mechanical characteristics of the soil and the technology of drilling a well (dry or with the use of drilling mud), the type of drilling fluid, the composition of concrete and its consistency, the method of concrete laying, the load on the pile

In general, the soil surrounding the pile absorbs loads in vertical and horizontal directions. To assess the retention capacity of the soil, various laws of contact interaction of the pile surface with the soil environment are adopted in works [5-8]. In this work, using the results of research on the establishment of the laws of interaction of underground structures with various soils, the bending of the pile under the influence of the shear force applied in the upper section of the pile is considered. At the same time, depending on the value of the shear force, two characteristic zones are formed along the contact surface, where the contact force between the deflection of the pile and the soil obeys the elastic and elastic plastic laws of interaction. The boundary of the two interaction zones is an unknown quantity, and is determined in the course of the solution.

Method of solution

To describe the contact interaction of the pile with the soil in each zone, we take the Prandtl scheme, according to which the intensity of the transverse load acting on the surface of the pile (beam) depends on the deflection according to the bilinear law (Fig. 1a). Let us direct the axis of the ox vertically downwards, designate the *deflection of the beam in each zone through W1(x)* and W2*(x)* (Fig. 1b). In this case, the plastic zone begins to form closer to the upper section of the pile, where the shear force is applied.

$$EJ\frac{d^4W_2}{dx^4}+k_2W_2+(k_2-k_1)W_s=0 \quad \text{at } 0<x<x_0 \tag{1}$$

$$EJ\frac{d^4W_2}{dx^4}+k_1W_1=0 \quad \text{at} \quad x_0<x<L \tag{2}$$

here EJ -Bikity of the pile in the bend *k1, k2* -bed coefficients in each zone, and $k_1>k_2$, W_s - deflection of the pile in the cross-section, where the plastic law of interaction is formed, determined from experience, x_0 - the coordinate of the boundary of the two interaction zones to be determined, *L*–total length of the pile.

a) б)

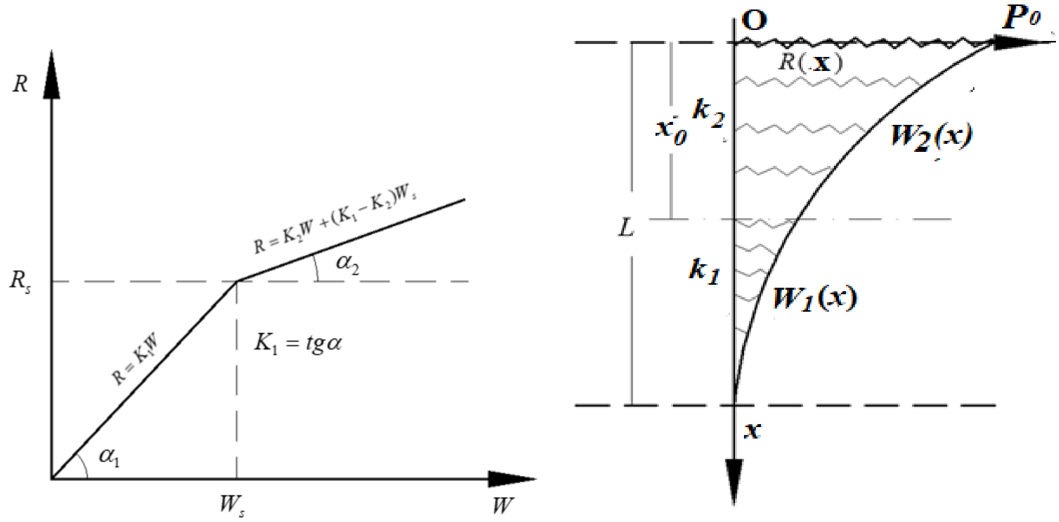


Fig.1 Diagram of the law of bending with the construction soil (a) and bending (b) under the action of a transverse load

Equations (1) and (2) are integrated under the following boundary conditions:

$$W_2''=0 \qquad EJ\frac{d^3W_2}{dx^3}=P \qquad \text{at } x=0 \tag{3}$$

$$W_1=0 \quad W_1'=0 \qquad \text{at} \quad x=L \tag{4}$$

$$W_1=W_s, \quad W_2=W_s, \quad W_1'=W_2', \quad W_1''=W_2'', \quad W_1'''=W_2''' \text{ at } \quad x=x0 \tag{5}$$

Equations (1) and (2) in dimensionless coordinates are represented as:

$$\overline{W}_2 = A_1 Y_1(\beta_2 \xi) + A_4 Y_4(\beta_2 \xi) - \frac{(\beta_1^4 - \beta_2^4)W_s}{\beta_2^4} - \frac{P_1 Y_3(\beta_2 \xi)}{4\beta_2^3}$$

$$\overline{W}_1 = \beta_2 Y_2[\beta_1(\xi - 1)] + \beta_3 Y_3[\beta_1(\xi - 1)]$$

$$\overline{W}_i = \frac{W_i}{L}, \quad \xi = \frac{x}{L}, \quad \beta_i = \sqrt[4]{\frac{k_i L^4}{EJ}}, \; \overline{W}_s = \frac{W_s}{L}, \; P_1 = \frac{P_0 L^2}{EJ}.$$

In here $Y_i(z)$ functions of the Krylov type

$Y_1(z) = chz\cos z, Y_2(z) = shz\sin z, Y_3(z) = shz\cos z - chz\sin z,\ Y_4(z) = chz\sin z - shz\cos z$

Constants *A1*, *A4*, *B2*, *B3* are defined from conditions (3-5), which give

$$A_1 = \frac{r_2 c_2 - r_1 d_2}{\Delta}, \quad A_4 = \frac{a_1}{a_{12}} - \frac{a_{11}}{a_{12}} A_1, \quad B_2 = \frac{c_1 r_2 - r_1}{\Delta}, \quad B_3 = \frac{a_0}{b_{12}} - \frac{b_{11}}{b_{12}} B_2$$

$$c_1 = a_{21} - a_{22}\frac{a_{11}}{a_{12}}, \quad c_2 = b_{21} - b_{22}\frac{b_{11}}{b_{12}}, \quad d_1 = a_{31} - a_{32}\frac{a_{11}}{a_{12}}, \quad d_2 = b_{31} - b_{32}\frac{b_{11}}{b_{12}}$$

$$r_1 = a_2 - a_{22}\frac{a_1}{a_{12}} + b_{22}\frac{a_0}{b_{12}}, \quad r_2 = a_3 - a_{32}\frac{a_1}{a_{12}} + b_{32}\frac{a_0}{b_{12}}, \quad \Delta = d_1 c_2 - c_1 d_2$$

$$a_{11} = Y_1(\beta_2\xi_0), \; a_{12} = Y_4(\beta_2\xi_0)\; b_{11} = Y_2[\beta_1(\xi_0 - 1)], \; b_{12} = Y_3[\beta_1(\xi_0 - 1)], \; a_{21} = \beta_2 Y_3(\beta_2\xi_0),$$

$$a_{22} = 2\beta_2 Y_1(\beta_2\xi_0), \; b_{21} = \beta_1 Y_4[\beta_1(\xi_0 - 1)], \; b_{22} = -2\beta_1 Y_2[\beta_1(\xi_0 - 1)], \; a_{31} = -2\beta_2^2 Y_2(\beta_2\xi_0),$$

$$a_{32} = 2\beta_2^2 Y_3(\beta_2\xi_0)\; b_{31} = 2\beta_1^2 Y_1[\beta_1(\xi_0 - 1)], \; b_{32} = -2\beta_1^2 Y_4[\beta_1(\xi_0 - 1)], \; a_{41} = -2\beta_2^3 Y_4(\beta_2\xi_0),$$

$$a_{42} = -4\beta_2^3 Y_2(\beta_2\xi_0), \; a_{41} = -2\beta_1^3 Y_3[\beta_1(\xi_0 - 1)], \; b_{42} = -4\beta_1^3 Y_1[\beta_1(\xi_0 - 1)], \; a_0 = W_s,$$

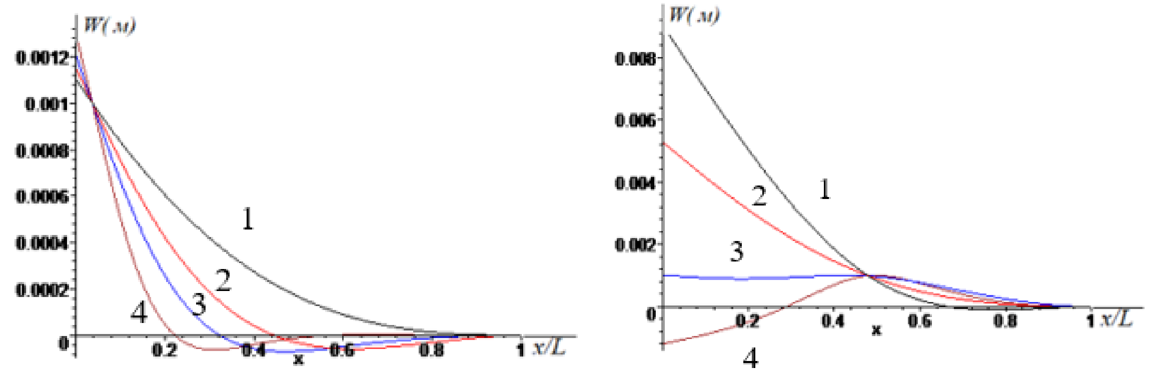
$$a_1 = \frac{\beta_1 \overline{W}_s}{\beta_2^4} + \frac{\overline{P}_0 Y_3(\beta_2\xi_0)}{2\beta_2^2}$$

Coordinate $\xi_0 = \dfrac{x_0}{L}$ is determined from the equation $A_1 e_1 - B_2 e_2 - r_3 = 0$ Where is

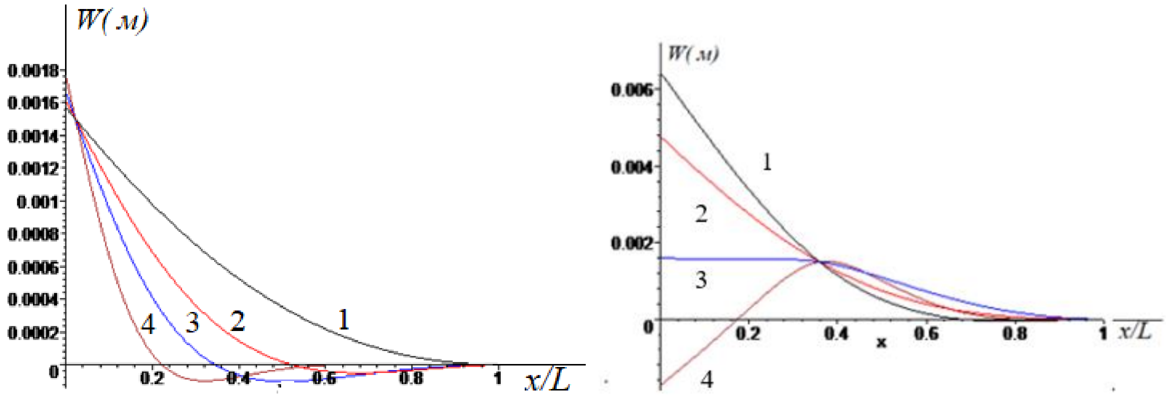
$$e_1 = a_{41} - a_{42}\frac{a_{11}}{a_{12}}, \; e_2 = b_{41} - b_{42}\frac{b_{11}}{b_{12}}, \; r_3 = a_4 - a_{42}\frac{a_1}{a_{12}} + b_{42}\frac{a_0}{b_{12}}, \; a_4 = p_0 Y_1(\beta_2\xi_0)$$

Fig. 2 shows the curves of change in the bending of the pile, along the length of the pile at $\overline{W}x/LP_1 = 1$ various values of the parameters $k = \dfrac{k_1}{k_2}$, Ws and β_2

k=1.8 *Ws=0.001м* *k=1.2*



k=1.6 Ws=0.0015м k=1.2



k=1.4 Ws=0.002м k=1.2

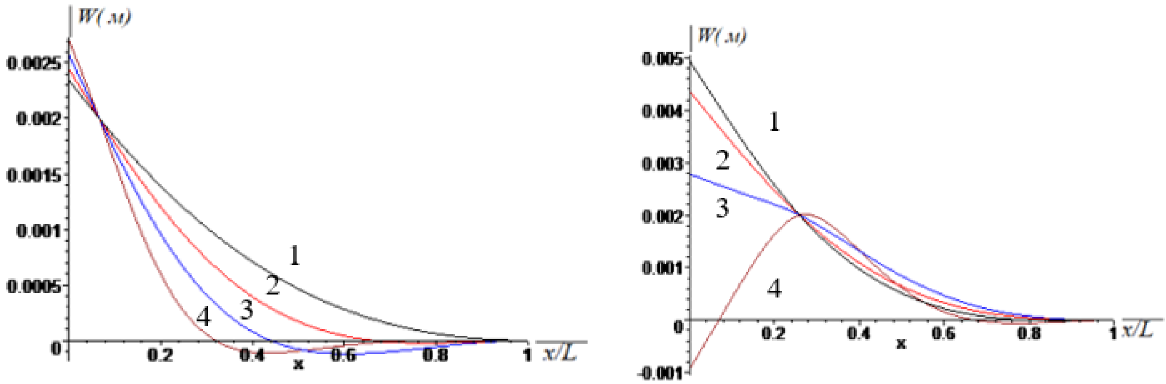


Figure 2. Curves of the distribution of pile deflections along the length of the pile for different values of the parameter $k = \frac{k_1}{k_2}$ Shifting W_s and the ratio of the stiffness coefficients of the contact parameter $\beta_2 = \sqrt[4]{k_2 L^4/EJ}$: $1 - \beta_2 = 0.5,\ 2\ 3\ \ 4 - \beta_2 = 1, -\beta_2 = 3 - \beta_2 = 5$

Conclusion

The growth $k = \frac{k_1}{k_2}$ of the ratio leads to an increase in the deflection of the pile and changes the nature of the change in its deflections along the length of the pile, and at the same time the deflections have practically positive values. The growth of the deflection Ws of the pile in the cross-section, where the plastic law of interaction is formed, leads to a significant increase in the deflection of the pile in its cross-sections. Thus, the presence of the bilinear law of the pile's interaction with the soil environment can significantly affect the deformed pile state. In particular, to lead to the redistribution of force factors along the length of the pile.

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