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SINGLE PILES SETTLEMENT UNDER THE ACTION OF NEGATIVE FRICTION FORCES

Nowadays, the use of pile-plate foundations has received extensive development, which takes into account the soil inclusion in the work under its plate part. We proposed a new design of a plate-pile foundation and an engineering method for determining the main parameters of such a foundation, where one of the parameters is the piles settlement under the action of the negative friction forces P_n. As far as is known, field testing of production piles using pressing-in loads is the most reliable method for determining their actual load-bearing capacity. We carried out full-scale tests of a multi-section pile with the loading at depth, on the basis of which a comparative analysis of the settlement of single piles from the action of the negative friction forces, obtained with the help of adapted and existing methods and experimental data

***Keywords:** ground base, pile-plate foundation, clearance, single pile, settlement, method*

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ОСІДАННЯ ОДИНОЧНИХ ПАЛЬ ВІД ДІЇ ДОВАНТАЖУВАЛЬНИХ СИЛ ТЕРТЯ

На сьогоднішній день широкого розвитку отримало застосування пальово-плитних фундаментів, де враховується включення в роботу ґрунту під його плитною частиною. Нами було запропоновано нову конструкцію плитно-пальового фундаменту та інженерну методику визначення основних параметрів такого фундаменту, де одним з параметрів є осідання паль від дії довантажу вальних сил тертя P_n. Як відомо, польові випробування паль на вдавлюючі навантаження є найбільш надійним способом визначення їх фактичної несучої здатності. Нами було проведено натурні випробування багатосекційної палі з прикладенням навантаження на глибині на основі чого проведено порівняльний аналіз осідань одиночних паль від дії довантажувальних сил тертя, отриманих за допомогою адаптованих існуючих методик та експериментальних даних.

***Ключові слова:** ґрунтова основа, плитно-пальовий фундамент, зазор, одиночна паля, осідання, методика*

Introduction. In the construction of multi-storey and high-rise buildings, where there are significant loads on a subsoil base consisting of not rocky soils, the so-called combined pile-plate foundation has being recently used to reduce the absolute and relative settlements, taking into account the inclusion of soil under its plate part [1].

Review of the latest sources of research and publications. For a real inclusion of the base under the plate in the monograph [2], a new construction of the plate-pile foundation was proposed (Figure 1), consisting of a plate 1 and piles 2 with diameter d, with a clearance 3 with height Δ (for example, in a concrete cap 4 below the plate), and the distance between the pile axes is nd. At the same time, the new design lacks the drawbacks of existing constructive solutions and methods for constructing such plate-pile foundations [3].

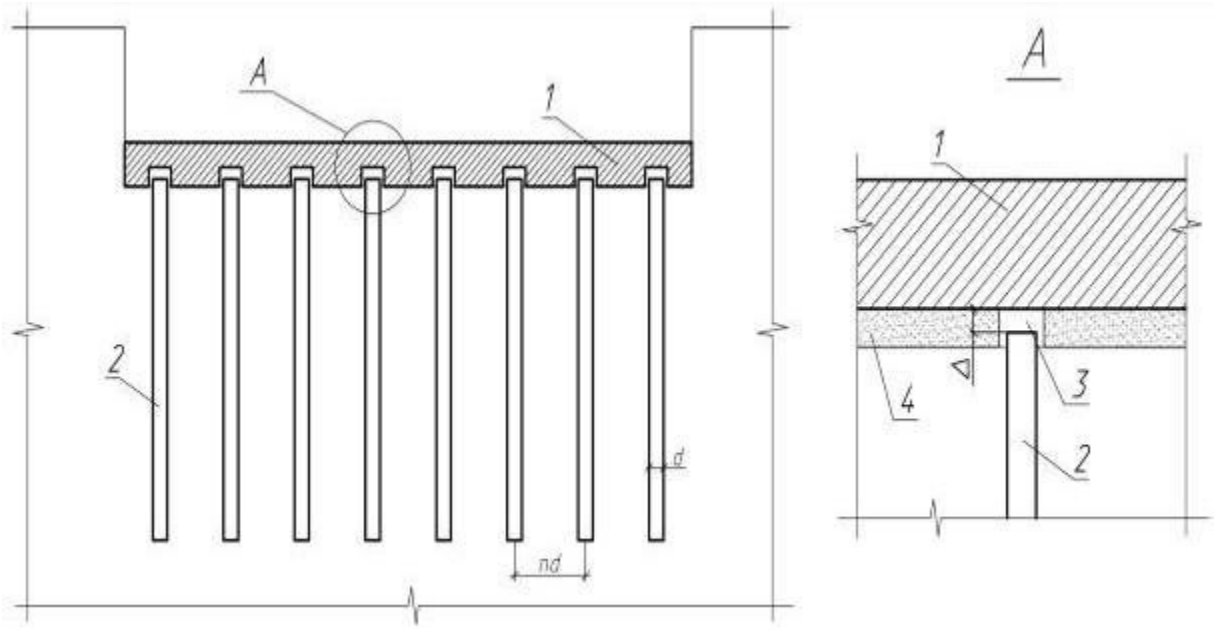

Figure 1 – Plate-pile foundation

The developed engineering method for determining the main parameters of such a plate-pile foundation based on the maximum allowable structure settlements [2] involves determining the height of the clearance Δ between piles and the plate part, which is equal to the value of additional pile settlement caused by the development of negative friction forces along their lateral surface within compressible thickness under the plate.

The selection of previously unresolved parts of the general problem to which the article is devoted. In the existing normative documents and scientific and technical literature, there are no methods for determining the settlements of piles from the action of negative friction forces P_n.

Formulation of the problem. The purpose of this paper is to perform a comparative analysis of the settlements of single piles from the action of negative friction forces obtained from various adapted methods with experimental data.

Main material and results. To determine the settlement of the pile $S_{pile}^{P_n}$ from the action of the negative friction force P_n, when the plate of the grillage works first, we present the calculation schemes in Figure 2, where the transition from the design scheme in Figure 2, a, but to the calculated scheme in Fig. 2, b, i.e. to the scheme of applying the load P_n to the pile at a certain depth. The lower part of the pile is located in a two-layer base with the corresponding deformation characteristics: E_1, v_1 and E_2, v_2.

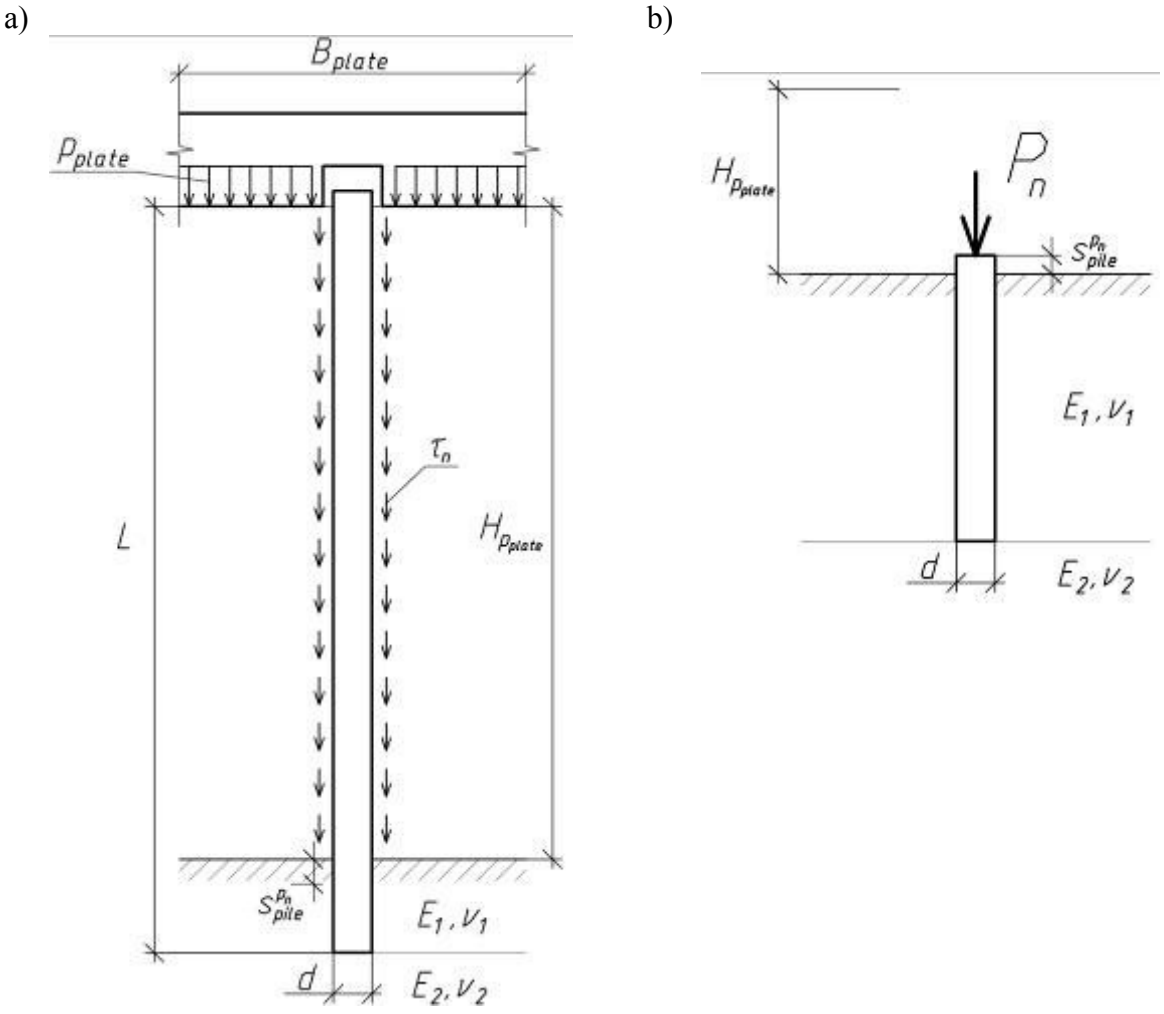

Figure 2 – Calculation schemes:
a) for the formation of friction forces τ_n on the lateral surface of the pile;
b) for determining the settlement of the pile from the action of negative friction forces

As far as is known, field testing of production piles using pressing-in loads is the most reliable method for determining their actual load-bearing capacity. In this field, the regulatory and the most common method is soil testing using piles, where a load is applied to the pile head by means of standard hydraulic equipment using counterweights or anchoring systems of various designs. While testing soils using piles, the stress-strain condition (SSC) of the «soil foundation – pile» system is being investigated using both conventional manometers and deflectometers, and modern transducers and equipment, whereby the load-bearing capacity is determined by means of different methods.

For the calculation scheme in Fig. 2, b we obtained the experimental values of the sediment for different loading levels by the force Pn when testing the soils by the full scale two-section pile by the «ONLY-DOWN» method [4, 5], namely the settlements of the lower part of the pile from the applied load at the depth (Figure 3). «ONLY-DOWN» method was proposed for testing production multi-section piles, which makes it possible to improve the reliability of the testing process and the accuracy of determining the value of the pile load-bearing capacity for pressing-in loads.

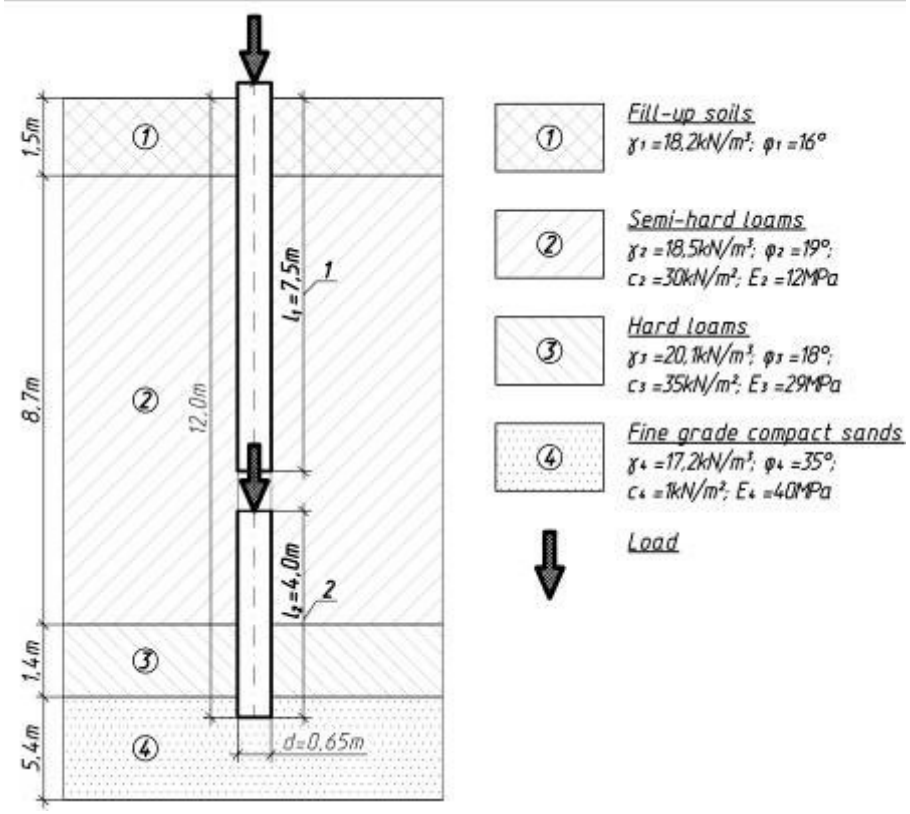

Figure 3 – Scheme of soil testing with a two-section natural pile by the «ONLY-DOWN» method:
1 – upper pile section; 2 – lower pile section

For the theoretical determination of the settlements of the lower section of the pile, the following adapted methods were considered:

– method for determining the settlement of a single pile in accordance with DBN [6];

– method for determining the settlement of the pile according to the design scheme of the conditional foundation in accordance with the DBN [6];

– method for calculating a single pile in a two-layer elastic environment, proposed by V.G. Fedorovskii [7, 8];

– method for calculating the settlement of a bored pile in a bilinear formulation, proposed by B.V. Bakholdin [10, 11].

The main factor of application of these methods is the correct determination of the proportionality limit or the boundary of the linear area of the dependence of the settlement on the load. In the case under consideration, the P_e load limiting the linear section of the pile settlement was determined in accordance with the recommendations of the DBN [6], namely:

$$P_e = 0{,}5P_u = 550{,}0 \text{ kN}, \quad (1)$$

where P_u – the value of the ultimate pile resistance based on the results of full-scale tests, equal to 1100,0 kN (Figure 4).

This approach was applied to all methods, except for the procedure for determining the settlement of the pile according to the design scheme of the conditional foundation. In this case, the conditional limit of proportionality was limited by the condition of point E.5 [8], when the average pressure under the base of the conditional foundation is less than or equal to the stress from the self-weight of the ground at the level of the base of the conditional foundation: $p \leq \sigma_{zg,0}$.

The results of calculations using the adapted methods are shown in Figure 4 in the form of theoretical dependences of the settlement of the lower section of the pile on the load, and also the experimental dependence on the test results is presented.

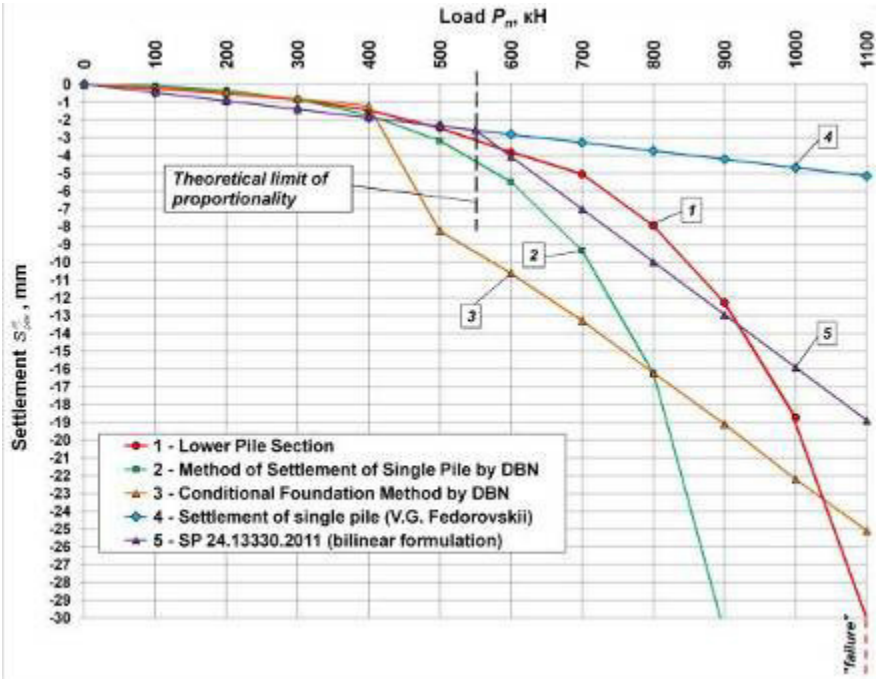

Figure 4 – Graphs of the theoretical and experimental dependencies of the pile settlements $S^{P_n}_{pile}$ on the negative friction force P_n

From the graphs obtained in Figure 4 it can be seen that all the adapted methods considered allow determining the settlement of the pile up to the limit of proportionality, i.e. up to the load limiting the linear dependence of the pile settlement on the load. The method for determining the single pile sediment, proposed in DBN [6], makes it possible to reveal the nonlinear nature of pile deformation after the proportionality limit, but overstates the real values. In this case, the most accurate method was used to calculate the settlement of a single pile from the action of additional load forces in a bilinear setting, proposed by B.V. Bakholdin [10, 11], which shows an inaccuracy of no more than 15,0% at any level of loading.

Conclusions. On the basis of carried out experimental and theoretical studies, the following conclusions can be drawn:

1. A comparative analysis of the settlement of single piles from the action of the negative friction forces obtained with the help of existing adapted calculation methods and on the basis of the results of testing the soils with a two-section in situ pile.

2. At this stage of the study, it is proposed to determine the settlement of the piles from the additional frictional forces using the B.V. Bakholdin method, which is represented in the Russian codes SP [11].

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