Barrettes under negative friction of soil surrounding

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ABSTRACT

Problem issues of negative friction force in barrettes and piles of a large diameter were analysed. Tests of such piles on some construction sites in Kyiv were considered. Barrettes were tested by Ostenberg's method and scale tests using the bored piles.

Cases of water saturation of soil bases above and below were considered. Comparative tables were made for the negative friction forces and bearing capacity values for barrettes and piles of a large diameter in special soil conditions were obtained.

Keywords: barrettes, negative friction forces, piles of a large diameter

1. RELEVANCE OF CONSTRUCTION ON UNSTABLE SOILS IN UKRAINE

Construction in Ukraine by increasing the load on base requires the use of pile foundations. In such cases barrettes and large diameter piles are used. In complicated geological conditions (special soils and areas of geological processes impact manifestation) the number of such foundations in the design of multi-storey buildings is 80-90%.

Barrettes are kind of piles arranged in cavities using a grapple in coherently-dispersed soils by technology "wall in ground" [1]. Large diameter piles are piles of different mode of arranging with a diameter greater than 600 mm.

Design of a reliable base for the building is a guarantee of a durable reliable operation. Therefore, the choice of the optimal solution of the foundation is a very important issue in compliance with the requirements adopted for this facility.

Almost more than 70% of the territory of Ukraine is covered by loess soils.

This subsidence of soils is observed at water saturation and requires further study of their physical and mechanical properties at the design.

Construction on unstable soils (loess, swelling, alluvial, bulk and arranging bases in flooded and landslide areas) require special approaches for each case of choosing the optimal design of foundations.

2. DETERMINATION METHODS AND CAUSES OF THE NEGATIVE FRICTION FORCES

In unstable soils there can be soil subsidence under the action of its own weight and the load caused by external factors. For example, there is a water

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saturation of soils at raising the level of ground water during the flooding accident or due to loss of water in the pipes. Experience shows that the consequences of accidents at pipelines damages are found after a long time.

Unstable soils have a higher porosity. The diameters of pores in these soils often exceed the size of the particles of soil by tens or hundreds times. Water saturation process occurs very quickly in time. There is a soil subsidence as a result [4].

2.1 The causes of the negative friction forces

Loading friction forces are forces arising on the lateral piles surfaces and piles foundations if there is a subsidence of soil base around them. If subsidence of soil around the pile exceeds the subsidence of piles and is directed vertically down, it has a load to the pile [2].

The forces of negative friction may occur in different circumstances:

- at mineral granules in the planning area;
- when highly compressible soils are deposited on the surface;
- at artificial or natural water lowering which causes an increase of its own soil weight and incomplete consolidation of soil foundations;
- vibration compaction of soil during the movement of transport;
- during the construction of shallow foundations which have a load to the pile base near the pile foundations;

The presence of the weak soil layer within the depth of the pile also increases the possibility of negative friction forces. Deformation of the weak layer can be so great that the soil layers above the bedding hang on piles and have additional load to them [3].

2.2 Methods for determining the forces of negative friction

There are many ways to determine the negative friction forces.

The first way which was included to the standards in Ukraine in 1976 recommends taking a specific value of negative friction forces as 0.01 MPa. But in fact the negative friction value depending on the soil conditions is changing. Therefore, the data in most cases exceed the values that were in norms.

The second method is static tests on the construction site. Work of the pile without the load of buildings and with the load is different. Consequently, the bearing capacity of the pile is lowered, and the value of friction forces is overstated.

The third way is definition of friction forces for theoretical solutions of V.V. Torhashov and P.I. Salnikov. A high precision of measurements by the proposed method is achieved by the fact that to the main pile the load of $P_G=0.5 \cdot F_{RK} \cdot A$ (A is an area upon which the pile stands, F_R is a calculated resistance at lower end) is applied. When soil subsidence is defined, the subsidence of the pile under the effects of load P_G and forces of negative friction D_{GK} is determined. The value of subsidence is put on the graphs and the value of total subsidence S_{SUM} is determined. Forces of negative friction D_{GK} acting on the base of the pile are determined as the difference between the total load F_{FK} and load P_G.

The fourth way is performed by the results of the pile testing by the static load with accuracy sufficient for practical purposes and using the graphs of $S = f(P_G)$ which consider the rate of subsidence increase in time.

The fifth way is performed by the results of the pile testing for compression and pulling. The force of negative friction D_{GK} is approximately equal to limiting resistance F_u of soil shift on the lateral surface of the pile.

The sixth way. According to the old normative documents the definition of negative friction D_{GK} using experiential data is recommended. In the absence of such data it is necessary to take the tabulated values of negative friction under existing rules [2]. But the results of field tests taken in accordance with the standards in most cases reduce their real values by one or two times.

2.3 Examples of water saturation of the soil above and below

During barrettes testing it was found that on construction sites №1 and №2 the upper layers of soil are sands of medium density saturated with water. Therefore, it is possible to have lowering of groundwater level or the effect of vibration which can lead to additional subsidence within these layers.

When planning the construction site №3 the unstable upper soil layers (loess and sandy loam) were cut off.

On this area ground waters lie under the lower end of the barrette. They are powered at the expense of the Dnieper River. When there are seasonal variations of groundwater levels it is possible to have a raise of them and as a result the water saturation of the lower layers of sandy soil.

Let`s consider the case of soil water saturation above and below (see Fig. 1).

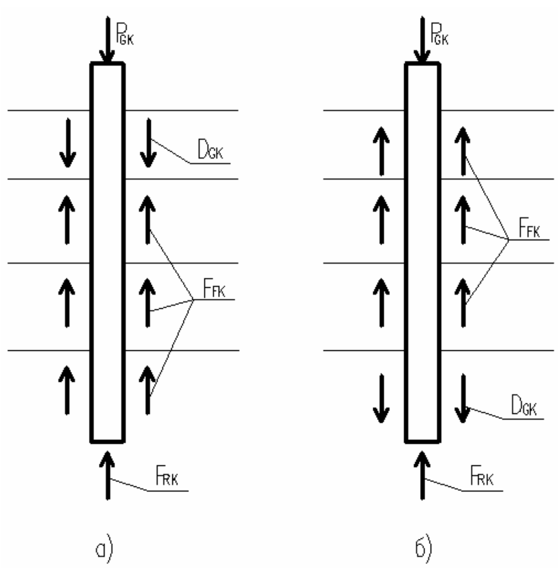

Fig. 1. Scheme of soil water saturation:

a) water saturation above, b) water saturation below

The general formula for calculation of the bearing capacity of the pile at negative friction forces:

$$F_{GK}=F_{RK}+F_{FK}-D_{GK},$$

where F_{GK} and F_{FK} are respectively characteristic values of resistance of the pile on the lower end and on the lateral surface; D_{GK} is a characteristic value of negative friction effecting the pile.

At water saturation above the calculation of the pile capacity is performed according to the scheme a) and at water saturation below it is performed according to the scheme b).

3. DEFINITION OF NEGATIVE FRICTION FORCES BY BARRETTES TESTING RESULTS AND CALCULATIONS

On the first construction site the testing was conducted by the Osterberg's method. Three o-cells placed at the bottom of barrettes were used. With their help the movement under the lower end of the barrette and on the lateral surface was determined.

Tables of normative documents [2] were designed for piles at a depth of 40 m. They consider the regional peculiarities of soil in Ukraine. Considering the general nature of changing the characteristics of the soil resistance R and f the author continued these tables to a depth of 85 meters, what provides all possible variants of piles placement by Ukrainian standards. Thus, the bearing capacity of barrettes with the length of 63.3 meters was calculated.

On the second construction site the tests were conducted on root piles with a diameter of 620 mm. According to calculations [2] the bearing capacity of piles is 4500 кN. On the basis of these calculations the bearing capacity of barrettes is determined.

Tests using the bored piles with a diameter of 820 mm were performed on the third construction site. According to their results it was concluded about the increase of deformation modulus of the last five layers of soil by three times for calculation of barrettes.

When determining the bearing capacity of large diameter piles it is necessary to use the processed test results of bored piles and values of scale factors.

European norms [5] allow the use of model piles to determine the bearing capacity in conditions when their diameter differs from the diameter of field ones by no more than in two times.

Barrettes calculation results at the water-saturated soil above and below are given in Table 1.

Table 1. The results of barrettes testing by static load on the construction sites of Kyiv

№	Object name, length l, m, cross-section or diameter of the pile, m	Bearing capacity of the lower end of the pile F_{RK}, kN	Negative friction on the lateral surface D_{GK}, kN	Bearing capacity on the lateral surface F_{FK}, MN	Bearing capacity according to DBN, F_{GK}, kN	Bearing capacity according to the test results F_d, kN	Difference, %
1	2	3	4	5	6	7	8
1	Sky tower *l*=63.3; *B*$_{23}$- 1.2×2.8	Natural soil moisture					9.92
		58.62	-	20.2	78.82	84	
		Soil water-saturation above					
		58.62	3.92	16.3	71		
2	Parus *l*=28,6; *B*$_1$- 2.8×1 *B*$_2$, *B*$_3$- 2.8×2.8	Natural soil moisture					34.4 32.4 32.4
		11.06 18.17 18.17	- - -	13.0 19.1 19.1	24.06 37.27 37.27	The test results of root piles	
		Soil water-saturation above					
		11.06 18.17 18.17	4.15 6.11 6.11	8.87 13.1 13.1	15.78 25.16 25.16		
3	Mirax plaza, *l*=32.7 *E*$_1$- 2.8×0.8	Natural soil moisture					2.78
		12.32	-	15	27.32	The test results of bored piles	
		Water saturation of the soil below					
		12.32	0.38	14.6	26.56		

Note: barrette B1 is rectangular sectional, barrette B2 is tee-sectional, and barrette B3 is cross-sectional.

Water saturation of the soil above and below has different negative friction forces. At water saturation above the thickness of soaked base layer is gradually increased and therefore, the subsidence of the pile is increased causing the increase of negative friction force. The obtained values D_{GK} for soil conditions in Kyiv confirm this conclusion.

Slightly different picture is observed at water saturation above: on one hand, the rise of water level increases the base subsidence which leads to the increase of negative friction forces; on other hand, the water saturated base thickness is decreased. It has more than water saturated contact friction which reduces the rate of growth of negative forces. At achievement of a certain level of water saturation front these processes are balanced and at the subsequent rise of ground waters the negative friction force is decreased [3].

Negative friction forces are inextricably connected with the determination of the pile bearing capacity. In accordance with the calculations this difference can constitute a minimum 2.78% (water saturation below) and a maximum 34.4% (water saturation above).

In accordance with the obtained results the determined value of barrette bearing capacity is influenced by a large number of factors:

- piles diameter and depth of laying;
- the bearing layer of the base;
- water saturation and unstable soil layers;
- pile testing methods (static scale tests or Osterberg's method).

4. CONCLUSIONS

According to the results of tests and calculations of large diameter piles and barrettes it was found that the negative friction forces on the lateral surface are inextricably connected with the value of the bearing capacity and quite significantly affect it.

When designing deep foundations it is necessary to pay attention to construction site soil conditions, namely the presence of unstable layers deep in the soil and groundwater level and adopt the guaranteed value of bearing capacity of piles taking into account the possibility of manifestation of negative friction.

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REFERENCES

1.DBN B.2.2-24-2009 Buildings. Designing of high-rise residential and public buildings/ Ministry of Construction in Ukraine, Kiev 2009. - 154 p.

2.DBN 2.1-10-2011Bases and foundations of buildings. General design provisions. / Piles and pile foundations / Ministry of Construction in Ukraine, Kiev 2011. - 54 p.

3.Karpenko D.A. (2005) "Investigation of bearing capacity of pile in loess soils depending on the type of water saturation of soil base" (Eds: Kornienko N.V.), Promstroyniiproeject, Donetsk.

4.Dolmatov B.I. "Mechanics of soils, bases and foundations" (Eds: Bronin V.N., Karlov V.D., Mangushev R.A.), stroyizdat, Leningrad, Moscow.

5.Eurocode 7: EN 1997-1:2004. Geotechnical design – Part 1: General rules.

6. Patent №1158676, Russian Federation, SU 1158676 A. The friction piles in thawing soils / V.V. Torgashov, P.I. Salnikov.