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ABOUT APPLICATION OF SHORT PILES UNDER LATERAL LOAD ACTION ON UNDERMINED TERRITORY

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Abstract. The article devoted to question about rationality of use of short piles under lateral load action on undermined territory in the conditions of dense urban development. It is known that short piles are often used to transfer lateral loads to the ground from buildings and structures. For calculation of short piles under lateral load action on undermined territory the main groups of methods have been analyzed and their use for calculation has been substantiated. It should be noted about testing recommendations of short pile foundations under lateral load action.

Keywords: pile foundation; undermined territory; lateral load.

Introduction

Rapid urban growth determines the need for the regular revision of the requirements for socially significant objects. Most often it concerns the need for combining a large number of processes within a single building that leads to increase in required project areas. In view of the lack of territory in big cities there has been a constant increase in the volume of construction of high-rise buildings, buildings with underground areas, unique buildings including on undermined territory.

In the construction process of new buildings and structures above, under or around the existing ones the builders facing a deficit of free urban areas have the need for strengthening of the basement in order to prevent building deformations and for searching of new approaches in foundation engineering.

A key issue in the construction of buildings and structures on the undermined territories is joint work accounting of the base and foundations. Wrong design, base preparation and construction of the foundations can cause the construction performed according to the project will cease to satisfy the qualifying standards.

In service the structures constructed on the undermined territories are subjected to irregular sinking and lateral deformation as a result of earth handling to the goaf and formation of the subsidence trough on the surface.

As construction practice shows some individual accidents of the constructed buildings and structures are connected with the wrong design in the process of base preparation and construction of the foundations. Exactly during operation of these objects the foundation soils accumulate the sufficient deformations.

The rational design of the foundations during the construction in the special ground conditions is one of the urgent problems in the field of construction. The works of many scientists are devoted to foundation design problems of buildings and structures in the conditions of dense urban development and in the special soil conditions [1, p. 6].

For example, the researchers of the unique buildings and structures offer the technologies, such as injection piles or «top-down» in order to prevent some settlements and deformations of the buildings and structures located in close proximity to the construction site [5].

Today in construction short pile foundations are widespread especially in the construction of light buildings and structures. The increasing trend of pile construction in special soil conditions are prerequisites for their further use.

Current problem state

In the design of pile foundation it should be taken into account the results of civil-engineering surveys, geological and hydrometeorological surveys and prospecting of the construction site. It is necessary some information that characterizes the purpose, the design and technological features of the constructed buildings and structures as well as the conditions of their use, the loads acting on foundations, some local conditions of construction [7].

During the calculating of the pile foundations it should be taken into account some work features such as the depth of loading, the pile interaction in the soil, the soil compaction, the changing its physical properties and mechanical behaviors.

In some cases the pile foundation projects are made with large stock. Sometimes the pile capacity is used incompletely, the measured settlement far less than permissible load for building and structures. All this suggests that there are some unused reserves of the pile foundation capacity reducing the economic efficiency of its use. The further research in this field of foundation engineering is required. The most important task of structural engineering is maximum savings on costs provided operational properties' preservation of any construction. At the same time, it is «a must» to minimize explicit costs directly for construction as well as the design process including calculations and civil-engineering surveys.

Thus for the correct forecasting of joint work of the bases, short pile foundations and constructions it is necessary to have reliable methods of predictions of precipitation accumulated over a specified time period, to determine the structure bearing capacity, to evaluate foundation stability under all types of loads.

As a whole deep study and further improvement of the calculation methods of the short pile foundations on the undermined territories is one of the most important ways to improve economic efficiency and reliability of the pile foundation and buildings.

Numerical methods for calculating pile foundations

It is necessary to know the transferred loads to the pile foundation for efficient and reliable project design.

During the calculation of short pile foundations on the undermined territory under the lateral load the numerical methods are used, namely the finite difference method, the finite element method and the boundary element method as well as their different modifications [2].

At the initial stage of application of short pile foundations, when the scope of their application was relatively small, the pile bearing capacity and pile foundations in some cases were determined by means of static load tests. Any static load test is produced in order to find the correspondence of the real pile bearing capacity with the design load.

The data obtained during the static tests essentially differ by their accuracy and relia-

bility unlike the dynamic tests. But along with it the static tests are more difficult, expensive and time-consuming in comparison with the dynamic tests.

The finite difference method received the widespread use due to the fact that it can be applied to any system of the differential equations. But account of the boundary conditions task is bulky and difficult [1]. The accuracy of the numerical task solution depends on the number of nodes that form the grid area. Therefore it is necessary to deal with systems of higher-order algebraic differential equations.

When using the finite element method the body is divided into elements of finite size; the larger are the elements, the smaller are the number of equations. Reaction of each element to external and internal influences reflects the reaction of a small area of the body. The condition of continuity between the elements is usually imposed at nodes rather than all over the boundaries of the partition. The finite element method is a numerical solution method for solving partial differential equations as well as integral equations arising in solving problems of applied physics.

The finite element method is widely used in the solution of very wide range of science and technology problems due to its efficiency and capability relatively easy to take into account the real boundary conditions.

The boundary element method has found their application in the tasks related to potential theory, theory of elasticity and plasticity as well as in calculations for the bending of thin elastic plates, vibration of deformable bodies, wave propagation and fluid dynamics.

The boundary element method can be used in combination with other numerical methods, such as the finite element method and the finite difference method, that is in mixed wording.

Calculation of short pile foundations according to two groups of limiting states.

The calculation of short pile foundations and their base on the lateral load is carried out according to two groups of limiting states.

The first group includes all calculations of foundations for stability -the first limit state based on various schemes of base destruction. The second group includes calculations of foundations by displacements – the second limit state based on different models of the soil.

The first limit state is determined by bearing capacity – strength, stability or endurance. The first limit state is expressed by inequality [3]

$$N \leq F \qquad (1)$$

where N – design force from the sum of the effects of the design loads in the most disadvantageous combination;

F – bearing capacity being a function of their geometric dimensions, design strength of materials and coefficient of working conditions.

The second limit state is described by difficulties of appropriate maintenance or reduction durability as a result of invalid displacements – deflection, support settlement, angle of rotation, cracks etc.

The second group of methods of foundation design (by displacements) is based on theory of elasticity (Winkler theory) with coefficient of bed changed with the depth according to one or another law [2].

Some researchers take coefficient of bed «k» is permanent, other researchers changed with the depth. The stress-strain curves of soil will have corresponding view

$$\sigma_h = k_h \cdot u_h \qquad (2)$$

where σ_h – stress in the ground at depth *h*;

k_h – coefficient of bed;

u_h – lateral displacement at depth *h*.

The transition of the construction from one state to another depends on many factors. The most important are the following:

1. external loads,
2. mechanical characteristics of concrete and reinforcement
3. working conditions of materials and construction.

Pile foundations on undermined territory

The technical solutions of pile foundations have to take into account the geological study contained the calculation of expected deformations of the earth's surface and the geological data about the undermined earth stratum. It is also necessary to consider the results of the variant comparison of some types of piles within the feasibility study.

In order to reduce the efforts in pile foundations on the undermined territory the following aspects should be predicted:

- cutting a building or structure into compartments,
- rational constructive scheme for pile-grillage foundation,
- use of the reduced rigidity piles.
- Depending on the expected deformations of the earth's surface the undermined territories are divided into four groups (table 1) [1].

Table 1

Classification of undermined territories in maximum size of the expected deformations of the earth's surface

Territory group	Relative horizontal deformation of compression $\xi_h \cdot 10^{-3}$	Incline i, 10^{-3}	Radius of curvature R, км
I	$12 \geq \xi_h > 9$	$20 \geq i > 10$	$1 \leq R < 3$
II	$8 \geq \xi_h > 5$	$10 \geq i > 7$	$3 \leq R < 7$
III	$5 \geq \xi_h > 3$	$7 \geq i > 5$	$7 \leq R < 12$
IV	$3 \geq \xi_h > 0$	$5 \geq i > 0$	$12 \leq R < 20$

Depending on the value of the expected deformations of the earth's surface the pile foundations can be used:

- with friction piles – on territory group II–IV for all types of buildings;
- with end bearing piles – on territory group III–IV for buildings designed with a pliable constructive scheme, and for territory group IV for buildings designed with a rigid constructive scheme.

For the high-rise buildings (more than 5 floors) under the condition of maximum incline of the earth's surface the pile foundations can be used only on undermined territory group II–IV [1].

The use of the lateral piles on territory group I and the use of the end bearing piles on territory group I and II are allowed only with special feasibility study.

Testing recommendations of short pile foundations under lateral load

Pile load testing is recommended to perform for the purpose of determination of the pile displacement under lateral load action. Value of load stage should be no more than

1/10–1/15 of assumed normative lateral load on the pile [3].

At a given load stage lateral displacement of pile head is considered stabilized, provided that its increment is no more 0,01 mm in sand – for last hour, in clay soils – for last two hours [2].

Lateral load tests on piles are recommended to conduct in the following ways.

1) For buildings without crane loads – after stabilization of displacements at each stage of the load we can go directly to the next stage.

2) For buildings with crane loads – after stabilization of displacements at each stage of the load the partial unloading is carried out on one stage along the previous stage. Having set the value of residual and elastic deformation load is increased on two stages at once. At the end of the loading the full unloading is carried out with stages equal to one or two load stages.

According to GOST 5684-94 during the test the load on the piles should be increased up to the value causing displacement no more than a 30 mm displacement for square and rectangular driven solid section piles and round piles as well as cast-in-place piles; a 50 mm displacement for hollow round piles, shell piles and belled-up piles [4].

Conclusion

In the zone of influence on the undermined territory the lateral deformations of the earth's surface affect foundations and first of all their bearing capacity.

On close studying of pile foundation work on the undermined territory under lateral load action some different groups of methods and their modifications are used in order to predict the soil-structure interaction in a proper way.

Prediction of pile foundation work under lateral load action is fairly difficult. This prediction includes taking into account some changes in the properties of the ground during pile-driving, some features of the stress state of the surrounding soil, force distribution in each pile along the lateral surface and under the tip, force distribution between the piles depending on the level of the pile driving.

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