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Prediction of the bearing capacity and optimization of the pile length based on the geoinformation database

Prédiction de la capacité portante et optimisation de la longueur du pieu sur la base de la base de données de géoinformation

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ABSTRACT: The rapid growth in the construction of megacities and new capitals requires operational information when planning and building the foundations. Today, the most preferred type of foundation is driven and bored piles. If the lengths of piles is determined incorrectly during the designing, it may lead to an additional increase in the cost of installing pile foundations. In this regard, it is very important to determine correctly the bearing capacity and optimize the lengths of piles in the soil conditions of Nur-Sultan city by using a geographic information database. The article considers the program “Geoinformation database” for the city of Nur-Sultan, which allows not only to reflect the available data in the form of maps and various property fields, but also to analyze data, to model geological fields in time and space, as well as to obtain the necessary information for the purpose of substantiating design work in construction and planning the development of the city.

RÉSUMÉ: La croissance rapide de la construction de mégapoles et de nouvelles capitales nécessite des informations opérationnelles lors de la planification et de la construction des fondations. Aujourd'hui, le type de fondation le plus préféré est celui des pieux battus et forés. Si les longueurs des pieux sont mal déterminées lors de la conception, cela peut entraîner une augmentation supplémentaire du coût d'installation des fondations sur pieux. À cet égard, il est très important de déterminer correctement la capacité portante et d'optimiser les longueurs de pieux dans les conditions du sol de la ville de Nur-Sultan en utilisant une base de données d'informations géographiques. L'article considère le programme "Geoinformation database" pour la ville de Nur-Sultan, qui permet non seulement de refléter les données disponibles sous forme de cartes et de divers champs de propriété, mais aussi d'analyser des données, de modéliser des champs géologiques dans le temps et dans l'espace. , ainsi que pour obtenir les informations nécessaires pour justifier les travaux de conception dans la construction et la planification du développement de la ville.

KEYWORDS: Geoinformation database, design, building, pile, load bearing capacity.

1 INTRODUCTION

When designing piles, the main criterion is the length and bearing capacity of the pile, which can be determined both by analytical methods and by field (full-scale) testing.

Since numerous experimental methods for determining the bearing capacity of piles, performed by various methods, confirm the greater reliability of the data obtained during field tests, and therefore are the most reliable. So far, the calculation results can only approach them with varying degrees of accuracy. Therefore, it is advisable to introduce a confidence factor for an accurate analytical determination of the bearing capacity, justified by field observations, taking into account various types of foundation.

In the engineering and geological conditions of the city of Nur-Sultan, the most preferable type of foundation is driven and bored piles, where long piles are used. This can lead to higher construction costs. In this regard, it became necessary to study the bearing capacity and optimize pile lengths using the geoinformation database program.

2 STUDY OF THE GEOTECHNICAL ENVIRONMENT OF THE NUR-SULTAN CITY

To assess the engineering-geological conditions in the built-up area of the city of Nur-Sultan, based on the materials of engineering-geological surveys, the program "Geoinformation database" was created for the first time (Zhussupbekov A et al., 2021, Zhussupbekov A. et al., 2019). This program currently includes data from 2,500 drilling sites, 1,500 static sounding points and 575 dynamic sounding points, which allows regional soil conditions to be analyzed before detailed research (Figure 1). The program "Geoinformation database of the city of Nur-Sultan" made it possible to analyze and systematize data from survey reports with the construction of a digital model of the engineering and geological structure of the territory. These data made it possible to investigate regional soil conditions. The physical and mechanical properties of soils were analyzed and six main geotechnical elements (EGE) were identified (Alibekova N. et al., 2019):

- EGE-1 - technogenic deposits (tIV) are represented by top soil (EGE-1a) and backfill soil (EGE-1b);
- EGE-2 - alluvial mid-Quaternary modern deposits (QII-IV) are represented by clayey soils, consisting mainly of loams (EGE-2a) with interbedding of sandy loam (EGE-2b), clays

(EGE-2v) and silt (EGE-2d), through all depth, they have lenses and interlayers of sands of various sizes up to 1-3 cm, and up to 10 cm;

– EGE-3- alluvial mid-Quaternary sand and gravel formations a (QII-IV) consist of sands of various sizes (EGE-3a), gravelly sands (EGE-3b) and gravel soils (EGE-3v);
– EGE-4 - eluvial formations of the weathering crust e (C1) are presented in the form of loams and clays with lenses and interlayers of sandy loam and inclusions of rubble soils;
– EGE-5 - eluvial formations of the weathering crust e (C1) are presented in the form of rubble soils;
– EGE-6-sedimentary rocks of the Lower Carboniferous (C1) are represented mainly by sandstones, which are interbedded with siltstones and mudstones of the same age throughout their thickness.

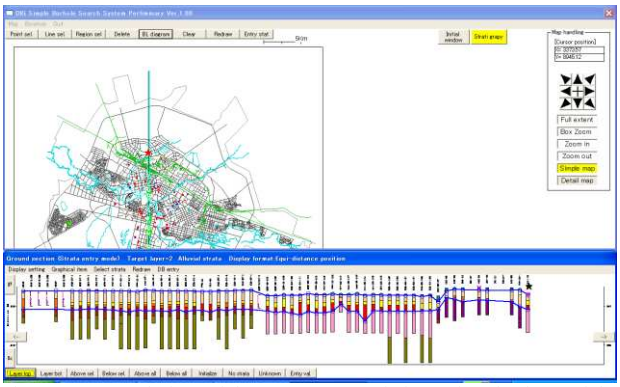
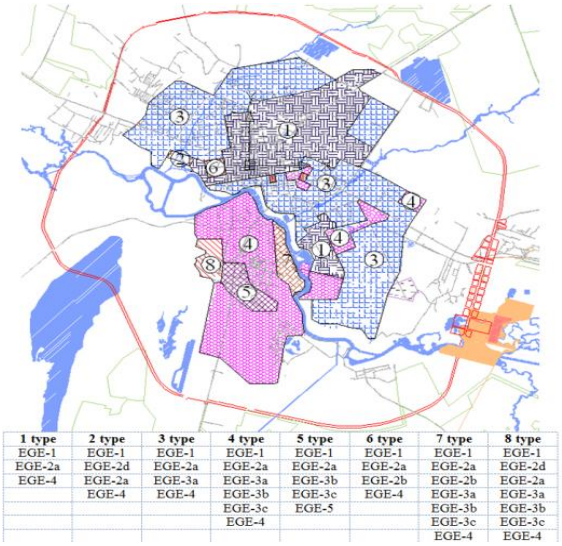


Figure 1. General view of the program "Geoinformation database of the city of Nur-Sultan"

Based on the assessment of the built-up area of the city, on which six main engineering-geological elements were identified and the analysis of the physical and mechanical properties of soils, it can be noted that the created program "Geoinformation database" allows you to divide the built-up area into conditionally homogeneous zones (by type of foundation). In addition, with the help of the program, geotechnical sections were built, which made it possible to assess the conditions of soil occurrence. Based on the analysis of the obtained sections, it was revealed that these elements form about eight types of bases before bedrock (Figure 2).



1 type	2 type	3 type	4 type	5 type	6 type	7 type	8 type
EGE-1	EGE-1	EGE-1	EGE-1	EGE-1	EGE-1	EGE-1	EGE-1
EGE-2a	EGE-2d	EGE-2a	EGE-2a	EGE-2a	EGE-2a	EGE-2a	EGE-2d
EGE-4	EGE-2a	EGE-3a	EGE-3a	EGE-3b	EGE-2b	EGE-2b	EGE-2a
	EGE-4	EGE-4	EGE-3b	EGE-3c	EGE-4	EGE-3a	EGE-3a
			EGE-3c	EGE-5		EGE-3b	EGE-3b
			EGE-4			EGE-3c	EGE-3c
						EGE-4	EGE-4

Figure 2. Geotechnical map of zoning by type of foundation

3 FORECAST OF BEARING CAPACITY AND ZONING OF THE TERRITORY OF NUR-SULTAN FOR OPTIMIZATION OF PILE LENGTHS

Design practice shows that with a significant thickness of the layer of weak soils, the choice falls on pile foundations, the lengths of which can be quite significant and different, ensuring the support of the pile points on the underlying dense soils, but poorly considering the upper layers of the base. At the same time, the experience of pile driving, accumulated recently, and the results of their tests indicate that designers overestimate the length of piles by an average of 1-2 m, which causes an additional rise in the cost associated with the need to cut down protruding heads using specially created mechanisms, and sometimes even manually.

Since the bearing capacity of a pile is determined not only by the limiting state of the material of the pile or soil near it, but also by the magnitude of the load corresponding to the permissible draft for a certain type of structure. In this case, the bearing capacity of the pile on the ground depends on the mechanical properties of the soil and on the method of installation or immersion of the pile. The nature of the work of a pile under the influence of a static load is also greatly influenced by the changes occurring in the surrounding soil during pile driving.

Consideration of materials for some districts of Nur-Sultan confirms that situations arise when the bearing capacity of a pile during field tests is 2 times or more high than the design load during construction.

In this regard, in order to more reliably determine the bearing capacity of piles and reduce the cost of conducting expensive domestic tests, a comparison was made of the bearing capacity of piles, determined by analytical and experimental methods, using the accumulated material from previous tests and processing it using computers.

In this case, more reliable results of the bearing capacity of piles can be obtained during static tests (Zhussupbekov A., Iwasaki Y. et al., 2019). However, the number of pre-design static tests of test piles is very limited to 2-4 piles per blocks due to the high costs of carrying out these tests. It was revealed that, according to the results of static tests of piles, the bearing capacity of the piles, brought to the unloading settlement equal to 6 mm (BS 8004: 1996, BS EN 1997-1:2004), corresponds to the results of the bearing capacity of the piles during dynamic testing of piles, as can be seen from the graph (Figure 3). Therefore, the calculated bearing capacity of piles was compared with the results of dynamic tests of piles, with the types of foundations being taken into account.

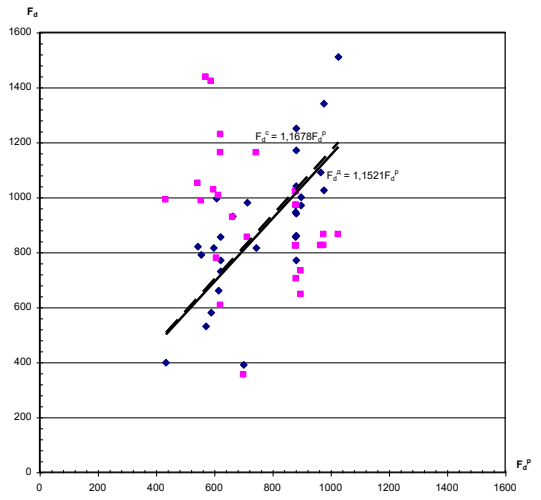


Figure 3. Comparison of the calculated bearing capacity with the results of dynamic and static tests of piles

As a result of the analysis, it was found that the bearing capacity of driven piles during dynamic tests in 98 cases (79%) and the bearing capacity of bored piles during static tests in 121 cases (59%) was greater than the load transferred to the pile during construction. Deviation from no more than 10% (both sides) was noted for 24 driven piles (19%), 85 drilled piles (41%). In 33 cases (26%) driven piles and 82 cases (40%) bored piles, the deviation was no more than twenty%. In 67 driven piles (54%), the bearing capacity during dynamic tests and 38 bored piles (19%), the bearing capacity during static tests significantly exceeded the loads transferred to the pile during construction. Consequently, these foundations have large and unjustified reserves.

Comparing the data of static and dynamic tests with analytical ones, we came to the conclusion that the maximum bearing capacity of the piles has not been used. This means that it is necessary to introduce a coefficient of reliability, which is necessary for an accurate analytical determination of the bearing capacity, substantiated by field observations.

Figures 4 and 5 show the coefficients of reliability for all tested piles, taking into account the type of foundation based on the comparison of the values of dynamic and static tests with the calculated values of the bearing capacity according to SN RK 5.01-03-2013, SP RK 5.01-103-2013.

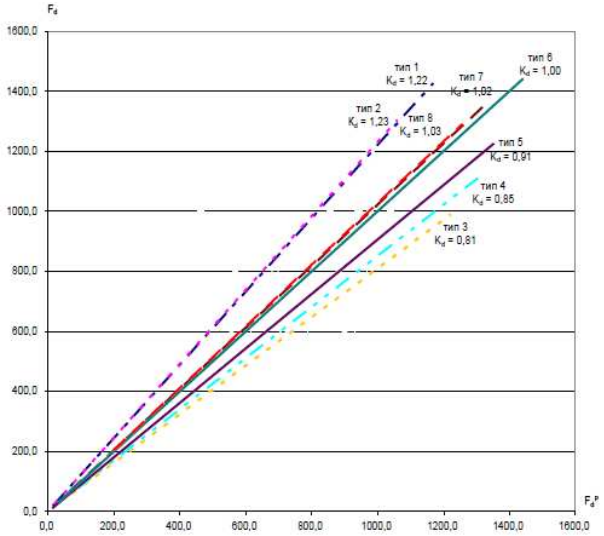


Figure 4. Values of the reliability factors based on the comparison of the values of dynamic tests with the calculated values according to SN RK 5.01-03-2013, SP RK 5.01-103-2013, taking into account the type of foundation.

The practical significance of increasing this coefficient is very high, since it opens up great opportunities for revealing hidden additional reserves of unused bearing capacity of the soils surrounding the pile.

The correct assignment of the coefficient of reliability will also make it possible to take into account many factors that were not reflected in the compilation of standard tables, the most important of which are: volumetric weight, porosity, angle of internal friction, specific adhesion and others.

Taking into account field observations under similar engineering and geological conditions, using the Geographic Information Database program, special geotechnical zoning maps were built to optimize the lengths of driven and bored piles (see Figures 6 and 7). However, the bearing capacity of the pile was not taken into account at the optimum length. This gap can be bridged in foundation design by using a confidence factor based on the type of foundation.

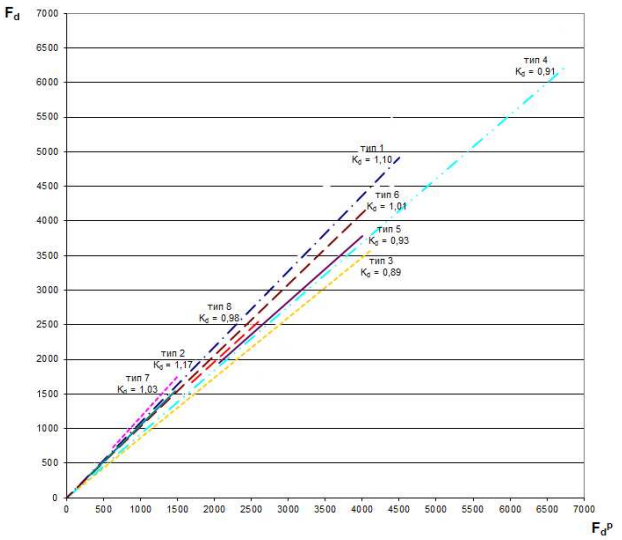


Figure 5. Values of the reliability factors based on the comparison of the values of static tests with the calculated values according to SN RK 5.01-03-2013, SP RK 5.01-103-2013, taking into account the type of foundation.

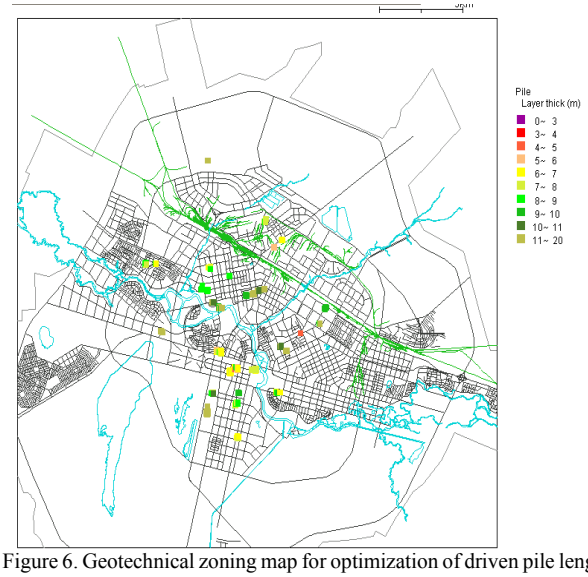


Figure 6. Geotechnical zoning map for optimization of driven pile lengths

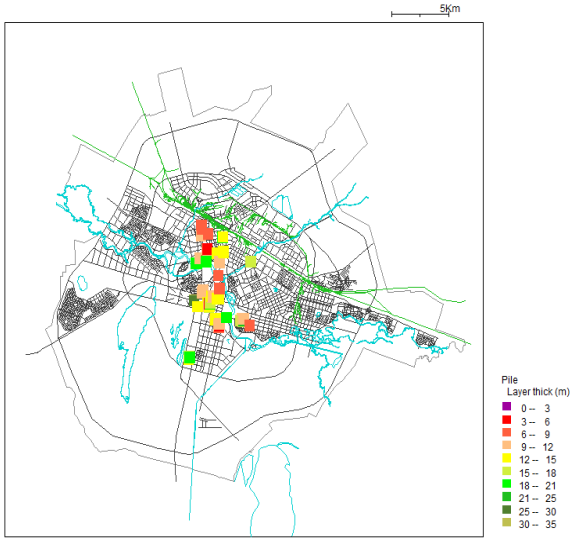


Figure 7. Geotechnical zoning map for optimizing the lengths of bored piles

4 CONCLUSION

A further increase in the efficiency of pile foundations can be achieved through the fullest use of the bearing capacity of the subgrade.

Analytical methods for assessing the bearing capacity of piles are significantly inferior in reliability to experimental research methods and do not provide sufficient accuracy in determining the design load allowed on a pile.

The analysis of the engineering and geological conditions of the territory of the city of Nur-Sultan and the experience in the construction of pile foundations on its territory in the context of a variety of building complexes and strata of soils made it possible to establish that the engineering and geological conditions of the construction site and the characteristic features of buildings and structures are not sufficiently taken into account when forming the development of quarters/blocks, the choice of foundations and technology for their construction. These circumstances lead to a significant rise in the cost of foundations and lengthening the construction time of buildings and structures.

Based on the data obtained, it can be noted that the developed program "Geoinformation database" and special maps of geotechnical zoning to optimize pile lengths will allow you to quickly obtain the necessary information for the purpose of justifying design work in construction and planning the development of the city's territory.

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