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COMPARATIVE ANALYSIS OF BORED PILES ACCORDING TO THEIR GEOMETRICAL VARIATIONS

ГЕОМЕТРИЯЛЫҚ ВАРИАЦИЯЛАРЫНА БАЙЛАНЫСТЫ БҰРҒЫЛАУ ҚАДАЛАРЫНЫҢ САЛЫСТЫРМАЛЫ ТАЛДАУЫ

СРАВНИТЕЛЬНЫЙ АНАЛИЗ БУРОНАБИВНЫХ СВАЙ В ЗАВИСИМОСТИ ОТ ИХ ГЕОМЕТРИЧЕСКИХ ВАРИАЦИЙ

Аңдатпа: *Қазіргі уақытта бұрғылау қадалары сияқты жоғары тиімді құрылыс материалдарын азаматтық құрылыс пен іргетас құрылысында пайдаланудың көптеген артықшылықтары бар. Бұрғылау қадаларының технологиясы үлкен, шоғырланған тік және көлденең жүктемелерде, күрделі геологиялық және инженерлік жағдайлары бар құрылыс алаңдарында, тығыз қоныстанған қалалық жерлерде және соққы немесе діріл жүктемелерінің әсерінен деформациялар туындауы мүмкін қолданыстағы ғимараттар мен құрылыстардың жанында қолданылады. Зерттеу бұрғылау қадаларының іргетас ретінде қасиеттері мен қолданылуын және олардың қазіргі заманауи құрылыс жағдайларында қолданудың маңыздылығын зерттеуге, сондай-ақ бұрғылау қадаларының жүк көтергіштік қасиетін оның диаметрі мен тереңдігінің өзгеруіне тәуелділігінің салыстырмалы талдауын жасауға арналған.*
Түйін сөздер: *бұрғылау қадалары, арматура, топырақ, жүк көтергіштік қасиеті, жер жұмыстары, іргетас, құрылысы.*

Аннотация: *В настоящее время, высокоэффективные строительные материалы, такие как буронабивные сваи, обладают различными преимуществами для использования в гражданском строительстве и строительстве фундаментов. Технология буронабивных свай находит применение при больших, концентрированных вертикальных и горизонтальных нагрузках, на строительных площадках со сложными геологическими и инженерными условиями, в густонаселенных городских районах и вблизи существующих зданий и сооружений, где могут возникать деформации при влиянии ударных или вибрационных нагрузках. Исследование посвящено исследованию свойств и применения буронабивных свай в качестве фундамента и значимости их использования в современных условиях гражданского строительства, а также проведению сравнительного анализа зависимости несущей способности буронабивной сваи от изменения ее диаметра и глубины заложения.*
Ключевые слова: *буронабивные сваи, армирование, грунт, несущая способность, земляные работы, фундамент, строительство.*

Abstract: *Nowadays, highly efficient construction materials such as bored piles have various benefits for use in civil and foundation engineering. The technology of drilling piles has applications for heavy, concentrated vertical and horizontal loads, on building sites with complicated geological and engineering* *conditions, in densely populated urban areas, and close to existing buildings and structures where deformations may occur from hammering or vibration loading effects. The study is devoted to the investigation of the properties and application of bored piles as a foundation and the significance of their use in the current civil engineering conditions, as well as conducting a comparative analysis of the dependence of the bearing capacity of a bored pile on the change in its diameter and depth of laying.*

Keywords: *bored piles, reinforcement, soil, bearing capacity, excavation, foundation, construction.*

Introduction. In many cases, it tends to be necessary that urgent construction work needs to be done close to existing structures and buildings during spot construction. In such circumstances, pile foundations are frequently used since they can support heavier loads than shallow-lying foundations and can also be more cost-effective due to the reduction in labor-intensive earthworks required during construction [1].

Nowadays, highly efficient construction materials called bored piles have various uses in civil and foundation engineering. Bored piles, which are typically used for building foundations, are cylindrical bodies made of concrete with or without reinforcing. High structural loads are transferred by them to lower, load-bearing soils. They can create a supporting wall for an excavation or steep slope when set up in rows or in a secant pattern, or they can block groundwater. The piles can have different lengths, diameters, materials, geometries, and arrangements depending on what they are used for [2].

In general, this investigation is devoted to the analysis of the properties and application of the bored piles as a foundation for a building through the study of previously done research. The purpose of the research is to determine the relevance of the usage of bored piles in the construction of buildings with special requirements and the calculation of the bearing capacity of bored piles, with further comparison of their dependence on the change in diameter of a pile and the depth at which lower-end bored piles are laid. The research will not only look at the benefits of the particular pile type but also at the reasons for using it more often as a foundation to improve the stabilization of foundations for buildings and other structures by providing lateral resistance against the pressure of soil or water.

Materials and methods of research. One of the major issues of the modern construction process is that the dynamic loads impacting neighboring structures present a significant challenge when constructing buildings on pile foundations in congested urban environments. The technology of bored piles may assist in finding a solution to this issue. Such piles are frequently employed in heavy-load conditions as well as when deeply compacted soils are present. Bored piles are frequently used as the foundation for bridges. The cost and duration of construction and maintenance projects can be drastically decreased by utilizing the most up-to-date technologies and following regulatory paperwork requirements when drilling structures [3].

Our country has extensive experience implementing bored piles on major, responsibly managed construction sites. It frequently occurs that urgent work needs to be done close to existing structures and buildings during spot construction. Undoubtedly, this sort of work demands the highest level of accuracy as well as the least amount of shaking and vibration. Modern bored piles are typically used to prevent the destruction of objects nearby during vibration loading or pile drive. On sites with the most challenging engineering and geological circumstances, they are used under extremely high concentrated horizontal or vertical stresses. The extraordinarily low noise level of bored piles is one of its most significant benefits [4].

As specified by the earlier investigations on technology of bored piles, since the early 1990s, St. Petersburg has seen a resurgence of technologies for the production of piles in the ground by boring and drilling, which has significantly decreased the usage of pre-ready piles (precast reinforced concrete piles). It should be noted that this city is located in a complex geotechnical location and also on the shore of the sea bay. Weak soil foundations, many historical buildings, and high groundwater levels pose great challenges for foundation builders. Such piles can be categorized into three primary groups based on how they were made: piles with excavation, piles with partial excavation, and piles without excavation along the pile's trunk. The “Fundex” technique, which has been perfected and applied by businesses like “Statika-Engineering”, “Geoisol”, “Old Town-Karst”, “Geostroy”, etc., can be used to create bored piles without excavation. In the Netherlands, the "Fundex" piling device's technology was created in 1960. By compacting the earth with a screw-in inventory steel pipe, whose lower end is sealed by a cutting tip left in the ground, a well is created beneath the pile without the need to remove the soil [5].

A rational area of application of drilling piles is the construction of fences of pit walls near streets with heavy traffic, near buildings and utilities, as well as in densely built-up areas, foundations of buildings, bridge supports, and other engineering structures. [6] These might include newly allotted areas, areas after preliminary engineering preparation, or undeveloped areas within an existing development zone. The purpose of bored piles is to move loads from a building or other structure to a ground base. These piles are also beneficial when there are soils that are heaving, expanding, or subsiding on the surface [7].

One of the main advantages of the usage of bored piles is the installation process, because it can be carried out all year round, regardless of weather conditions, and a high level of mechanization of work allows you to accelerate the pace of construction of fences and foundations. A drilling hole is excavated, a casing pipe is lowered into it, an armored frame is dropped into it, and a concrete mixture is poured into it to install the support structure. A monolithic structure capable of withstanding large weights, severe compression, and bending loads is created once the concrete has solidified [8].

According to the methodical manual on the construction of fences from bored piles, the technology of manufacturing bored piles consists of two interrelated primary works: drilling an excavation and laying a concrete mixture into it with the previous or subsequent installation of a reinforcing frame. The unique aspect of this connection is that both the drilling rig and the concrete mixture are temporary components. The existing regulations only govern the time period (no longer than 8 hours) between the completion of the drilling procedure and the start of concreting since their attributes swiftly deteriorate as the retention period increases, making them unsuitable. The concreting of the drilling hole should be completed before setting (after 1.5–3 hours from the moment of closing) of the first laid portions of the mixture, which makes a very tough key requirement for the technological process of manufacturing bored piles and requires a high production culture of the entire production complex: concrete plant, vehicles, roads, construction site, drilling installations [7].

It is necessary to adhere to the requirements of Construction Norms and Regulations 3.02.01, Construction Norms and Regulations 3.03.01, and Construction Norms and Regulations of RK 3.02-29 while laying foundations and foundations, as well as building standards for the organization of construction [9].

In the course of research, several mechanisms of bored piles installation were highlighted. For the installation of drilling piles underneath clay mortar protection, rotary drilling machines are used. The technology behind the heaps' gadget is as follows: A well is dug, its walls are mortared with clay (bentonite), and it is concretized by supplying concrete through a concrete-cast pipe that is lowered to the bottom of the well and slowly rises as the supply of concrete increases. Install metal cornices in a clay solution when setting up piles 30 meters in length or longer. The disadvantage of this method is that the clay solution weakens the concrete reinforcement's adherence.

The interaction between a pile and the soil, which is influenced by the soil properties (soil type and/or presence of hard stratum), as well as the installation method, determines a pile's load capacity. As indicated in Figure 1, loads from the superstructures are transmitted into the soils, and the resistance to loadings is provided by frictional force and end bearing. The friction that occurs between the pile and the surrounding soils, which is primarily controlled by the shear strength of the soils, generates the frictional force, or so-called shaft resistance. When the pile penetrates into hard strata, there is a significant amount of end bearing, or so-called base resistance [10].

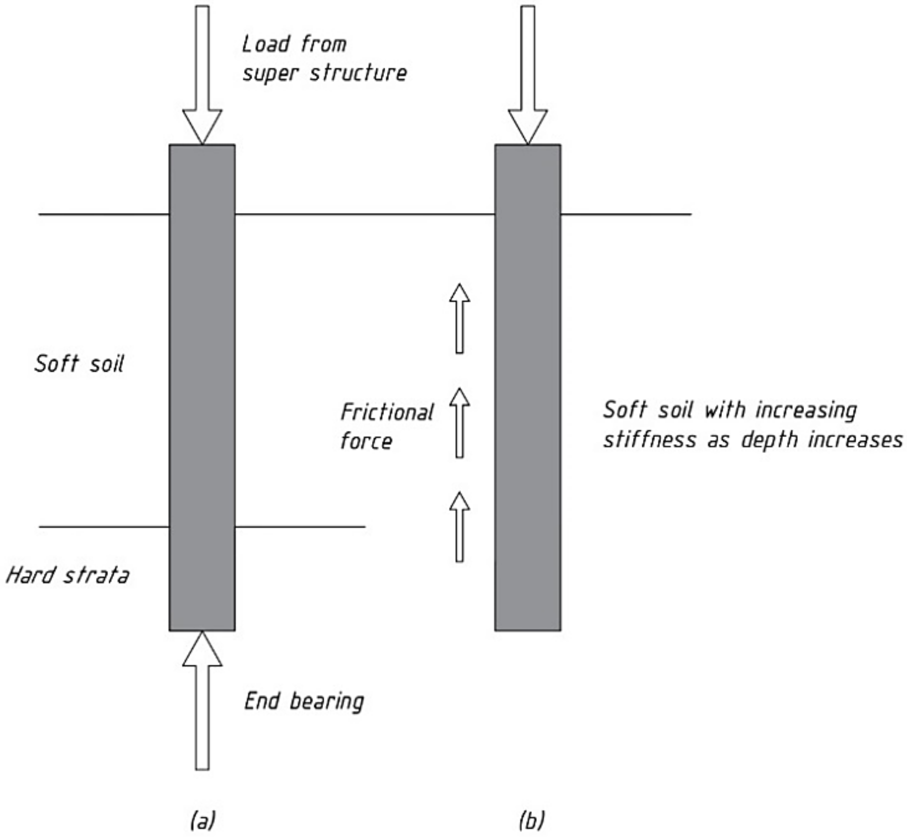

Figure 1. Load transfer mechanism of a pile foundation:
(a) end-bearing pile and (b) friction pile

The technique for building piles using short through-pass augers involves sinking the augers to the design depth, using a concrete pump to pump concrete through the inner pipe of the auger while simultaneously pulling it out, and then using a vibration loader to lower the metal frame into a well of concrete. The benefits of this method are the absence of vibration and shock, the high pile bearing capacity, high productivity, and the high quality of the pressure-supplied concrete that fills the well. The pace of the pile arrangement slows down when moving over refractory or semi-solid loams or clays, which is one of the drawbacks.

During the installation of piles with a continuous auger, the formation of piles occurs without additional fastening of the walls of the well. For soils with layers that differ greatly in strength, the technology is essential. Pressure is applied when supplying concrete. When pile compaction is impossible, such as when driving through a thick layer of sand or semi-solid and refractory loam, this approach is extremely useful. The concrete piles created with this technology are worthy due to its great productivity and quality [11].

The general assessment of the continuity of piles using dynamic tests that result in minor deformations is part of the general evaluation of the quality of piles that could have significant flaws or reduce the strength of the surrounding soil when they are installed. Other tests are carried out while the work is being done, such as sounding, vibration, or testing the chosen cores, as it is frequently impossible to identify such significant defects with the help of dynamic tests, such as poor concrete quality or insufficient thickness of the protective concrete layer, each of which can affect the operation of piles for a long time [12].

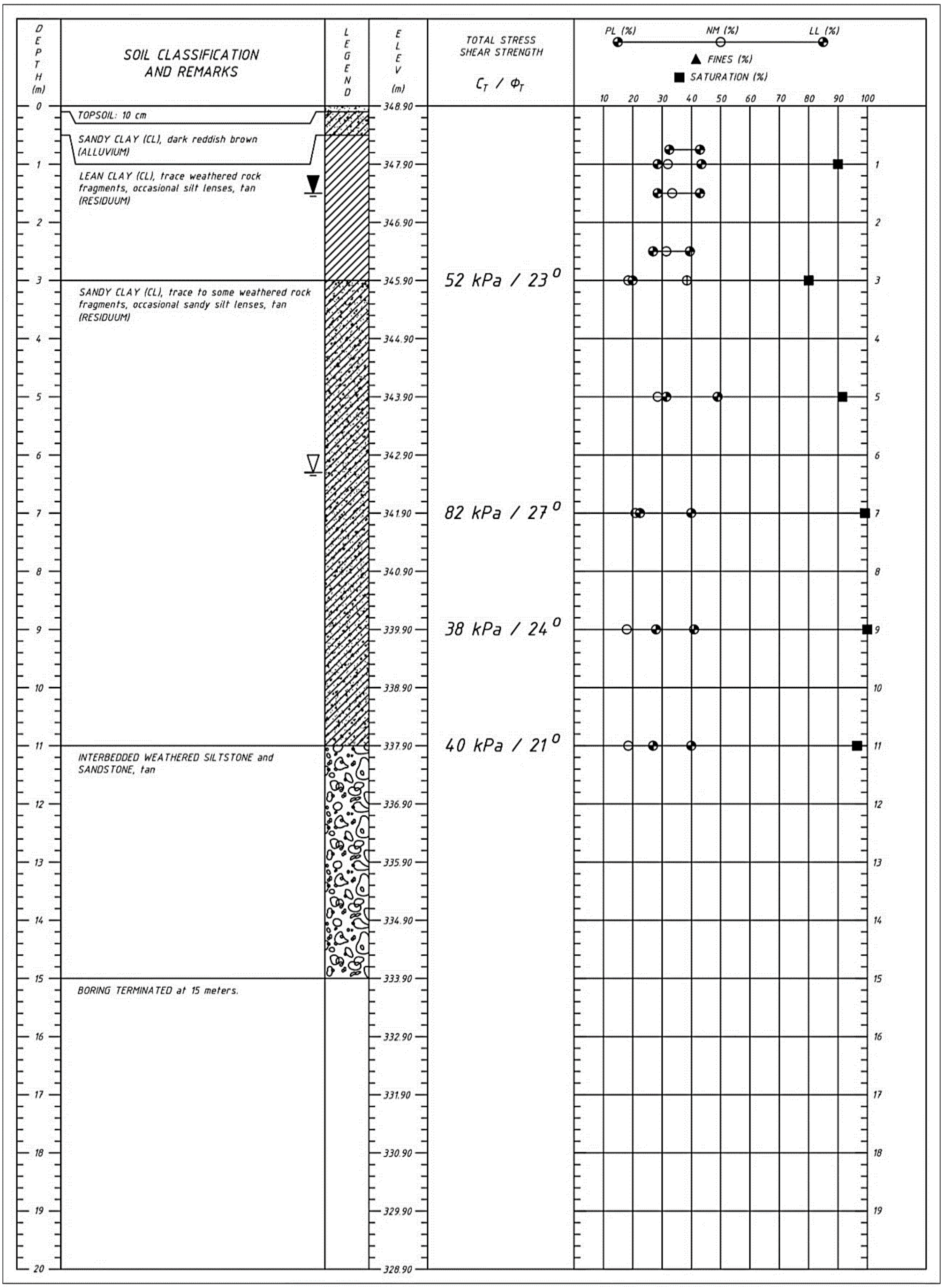

Figure 2. Soil classification and characteristics

The first group of limit states influences the calculation of pile foundations and their bases. In the present instance, it indicates that the bearing capacity of the soil at the base of the pile foundations is taken into consideration if significant horizontal loads, particularly seismic ones, are transferred to them (retaining walls, spacer structure foundations, etc.), if the structure is positioned on or near a slope, or if the base is composed of steeply falling soil layers [13].

According to the requirements of regulatory documents, loads and impacts, load safety coefficients, and conceivable combinations of loads considered in the calculations of pile foundations have been accepted. The estimated values of the physical properties of the materials and soils that are given in Figure 2 are applied in all calculations related to piles, pile foundations, and their bases [14].

The following formula is used to calculate the piles with and without broadening, as well as shell piles submerged in excavation and filled with concrete, working under a compressive load [15]:

$$Fd = \gamma c * (\gamma cR * R * A + u\Sigma fi * hi),$$

Where:

γ_c - the coefficient of the working conditions of the pile; in the case of its support on clay soils with a degree of humidity $S_r < 0.9$ and on loose soils $\gamma_c = 0.8$, in other cases - $\gamma_c = 1$;

γ_{cR} - coefficient of working conditions of the soil under the lower end of the pile; $\gamma_{cR} = 1$;

R - is the calculated resistance of the soil under the lower end of the pile, kPa, for a packed pile manufactured according to the technology, according to SP RK 5.01-103-2013; For $I_L = 0,2$ and the depth of 6 m, R = 800 kPa, and for $I_L = 0,2$ and the depth of 12 m, R = 1250 kPa.

A - is the pile-bearing area, m^2. Using the formula: $A = \pi * r^2$, the area of the cross section was found. For the diameter of cross-section 0,6 m, A = 0,28 m^2; for 0,8 m, A = 0,50 m^2; for 1 m, A = 0,785 m^2;

u - is the perimeter of the cross-section of the pile trunk, m. Using the formula: $u = 2*\pi*r$, the perimeter of the cross section was found. For the diameter of cross-section 0,6 m, u = 1,88 m; for 0,8 m, u = 2,51 m; for 1 m, u = 3,14 m;

f_i - is the calculated resistance of the i-th soil layer on the side surface of the pile trunk, kPa, accepted according to SP RK 5.01-103-2013; For $I_L = 0,2$ and the depth of 6 m, $f_i = 58$ kPa, and for $I_L = 0,2$ and the depth of 12 m, $f_i = 67,8$ kPa;

h_i - the thickness of the i-th layer of soil in contact with the side surface of the pile, m.

The calculation of bearing capacity is done taking into account the aforementioned formula and values. The results of the calculation are given in Table 1.

Table 1. The bearing capacity F_d depending on the depth and diameter of bored piles

Depth at which lower end bored piles are laid h, m	Bearing capacity F_d, кN		
	Diameter of the pile-bearing cross section d, m		
	0,6	0,8	1
6	878,2	1273,5	1720,7
12	1879,6	2667,1	3535,9

In many calculations, when bored piles are selected, they try to increase the length of the piles. While our method involves considering not only the length but also the width of the piles for the final design.

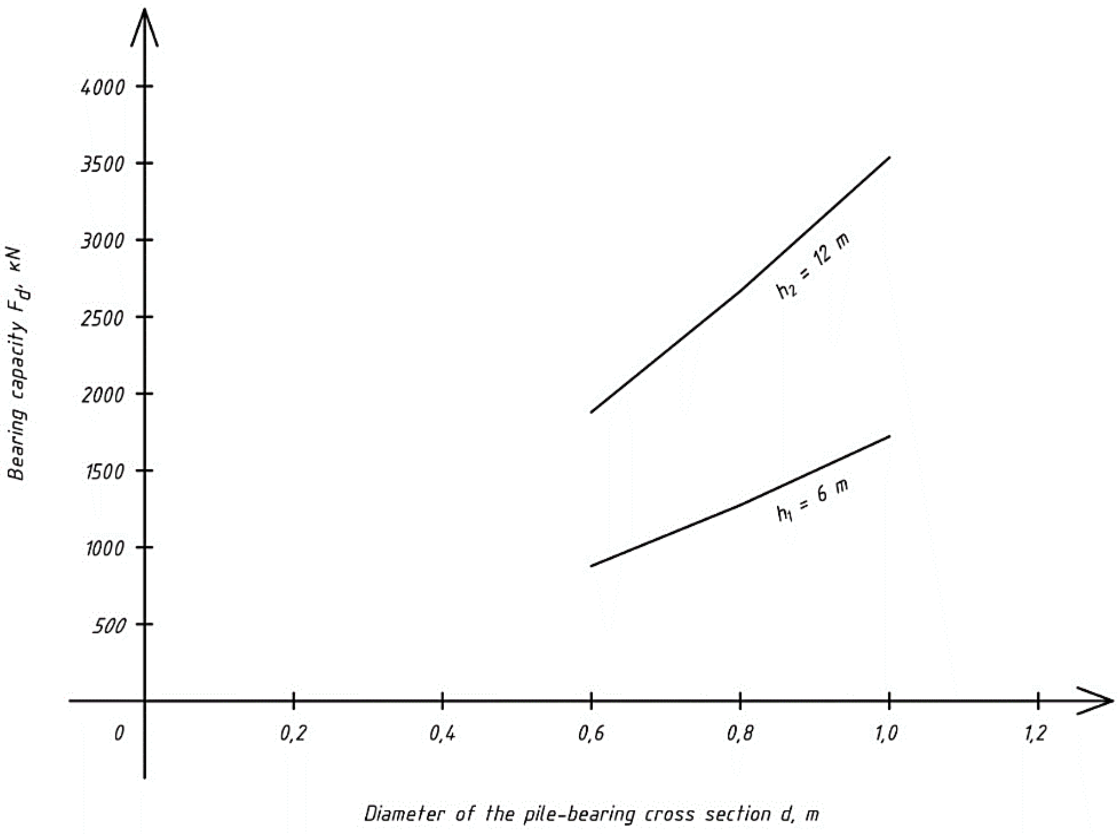

Figure 3. The bearing capacity F_d depending on the depth and diameter of bored piles

Results and discussion. Table 1 and Figure 3 demonstrate the dependence of bearing capacity on the depth at which the bored piles are excavated and the diameter of the pile-bearing cross section. As can be seen in Figure 3, the increase in diameter and length positively affects the bearing capacity of the bored pile. When the depth at which lower end bored piles are set was raised from 6 m to 12 m, the bearing capacity of a pile with a diameter of 0,6 m increased by about 115%, while for bored piles with a diameter of 0,8 and 1,0 m, the value of the bearing capacity doubled, or, by way of explanation, it was increased by about 105-110%. The results obtained demonstrate that the bearing capacity of piles with varying diameters is impacted in an equivalent manner by extending the length of bored piles.

On the other hand, at a pile length of 6 m, the bearing capacity of a pile grew by 45% when the diameter increased from 0,6 to 0,8 m and by 35% when the diameter of a bored pile rose from 0,8 to 1,0 m. When a pile's length was 12 meters, the bearing capacity of a bored pile increased by roughly 40% when the diameter went from 0,6 to 0,8 m and by approximately 30% when the diameter rose from 0,8 to 1,0 m. Taking into account the advancement of bearing capacity values in percentages, the results shown demonstrate that an increase in the depth at which bored piles are excavated has a more significant impact on enhancing bearing capacity than the expansion of the diameter of a bored pile.

Conclusions. Overall, this investigation focused on integrating prior studies to analyze the characteristics and application of bored piles as a structure's foundation. Consequently, it was determined how essential it is to use bored piles while constructing buildings with special requirements, and for the purpose of guaranteeing the bases' strength and stability, as well as to prevent the foundation shifting along the sole and tumbling over, the bearing capacity of the foundation was determined. In consideration of the aforementioned, bored piles are sustainable and essential materials for the construction of buildings and other structures under the challenging circumstances of congested urban development. According to the results obtained, it can be seen that the difference in the length of the piles is a multiple of 6 metres. According to this multiplicity the bearing capacity of the piles is 2.04-2.14. While for the diameter of the piles the multiplicity was 0.2 metres and the difference in bearing capacity is 1.32-1.45. In other words, during the design process, the widening of the diameter has a greater effect in terms of increasing the bearing capacity of the piles.

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