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M.I. Nikitenko[1] – *main author*
V.Yu. Zhuravsky[2]

[1]Doctor of Technical Sciences, Professor,
[2]Deputy Head, Chief Designer of the Department of Housing and Civil Engineering and planning Works
ORCID *[1]https://orcid.org/0000-0003-0856-0208*
[1]Belarusian National Technical University, Minsk, Belarus
[2]RUE Republican Unitary Enterprise Glavgosstroyexpertiza, Minsk, Belarus
@ *[1]michnikit@gmail.com*

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PILE FOUNDATIONS PROBLEMS IN THE BELARUS GEOTECHNICAL PRACTICE

Abstract. Some problems arising in the design, construction and testing of piles in the geotechnical practice of Belarus are presented, and the possibilities of their solution are outlined. Recommendations are given to improve the efficiency of pile foundations.

Keywords: pile, pile foundations, testing of piles, efficiency of pile foundations, pile forests.

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Introduction. In the geotechnical practice of Belarus, pile foundations have a large share in the construction and reconstruction of various facilities, which is due to the difficult engineering and geological conditions of the built-up areas, as well as an increase in loads on foundations with an increase in the number of floors of buildings and structures being erected [1].

Until recently, driven piles prevailed throughout the vast territory of the former USSR (about 80-90%) due to the captivating speed of their immersion. At the same time, significant disadvantages of driven piles were ignored: limited bearing capacity on the ground and even the manifestation of negative friction along trunks of constant cross-section, harmful dynamic effects on adjacent objects, etc. It is usually not possible to hammer finished piles onto design marks without well bores or underflow, which is inevitably accompanied by the appearance of so-called "pile forests" (Figs.1,2), overspending of material resources, increased labor costs and energy intensity [2].

As is known, the reinforcement of shafts, even in coaxially compressed reinforced concrete piles during immersion and pressed in during operation, is mainly due to their bending from their own weight in a horizontal position during slinging, transportation and storage. Violation of the rules for lifting and laying piles on objects leads to cracks (transverse, inclined and even longitudinal) in the trunks (Figs.2,3,4) and even to their breakdown due to incorrect distribution of bending moments along the length. Bending cracks are very typical for piles with trunk tension with high-strength rods in their center, i.e. in the neutral zone [3].

Fig.1. Piles not submerged to the design depths

Fig. 2. Piles not submerged to the design depths

The process of cutting down unloaded sections of piles is not only laborious, but also unsafe. There is a known case when even the presence of a helmet did not prevent an accident when hitting a worker with a cut piece on the head.

During the construction of panel houses, a method of leveling the marks of pile heads after felling has become widespread due to prefabricated heads placed on top of them with holes having an inverse taper for sealing single or groups of piles (Figs. 4,5). If there are advantages, such a solution is not without drawback. It cannot redistribute loads on piles with unequal values of their bearing capacity and sediment, unlike monolithic reinforced concrete grilling, which should be preferred [2].

Fig.3. Defects in pile trunks during incorrect laying on the soil surface

Fig.4. Pile field after cutting down the upper sections of piles and after laying prefabricated headrests on them

Research methods and conditions. To eliminate the ingrained vicious practice of sinking driving piles to design marks, which is not allowed in industrialized countries, let's look at the causes and factors leading to its occurrence.

Specialists engaged in pile driving usually refer to the occurrence of a design failure value, allegedly indicating that the required soil resistance and bearing capacity of the base have been achieved.

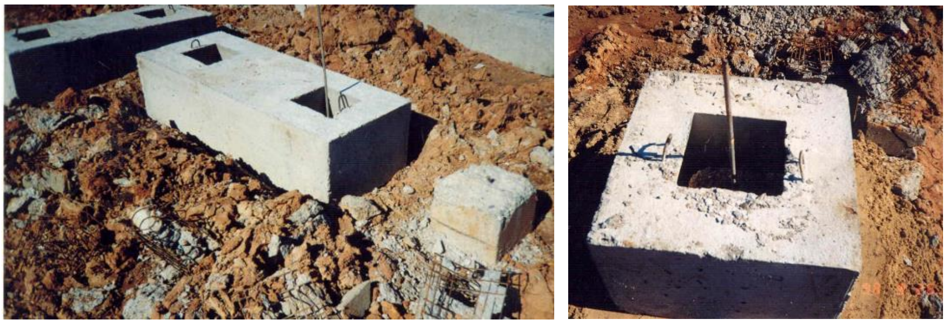


Fig. 5. Prefabricated headrests with conical cavities on paired and single piles before sealing them

The following considerations are not taken into account. The magnitude of the failure (this term itself is unfortunate), i.e. the sinking of the pile from a single blow at the end of the driving, can be distorted by many factors and phenomena:

1 - jamming of the pile with an overestimation of the resistance of coarse-grained and sandy soil with dilatant separation from the reversal of particles and an increase in the volume of the shear zone along the contact with the lateral surface of the trunk;

2 - slip of the pile following temporary jamming, when along the trunk, with further rotation of the particles and a decrease in the volume of the shear zone, a contraction occurs with a sharp decrease in soil resistance;

3 - saponification of plastic clay soil in connection with its transition to a fluid state with a decrease in shear resistance along the trunk and compression under the tip when turning cohesive water into free from shocks;

4 – the suction of piles in clay soils manifests itself in the form of their spontaneous immersion after the cessation of impacts due to the occurrence of a vacuum in the gap under the tip when lifting the pile from elastic deformations of the compressed trunk and the surrounding soil;

5 – the so-called false (actually underestimated) failure in water-saturated, low-filtering fine and especially dusty sands associated with large elastic deformations (pile lifting), since during dynamic shock pulses, a low-compressible water or even air (trapped gases) bubble appears for a short time under the edge;

6 – the dance of piles, expressed in the alternation of sharp dives of the pile and their decelerations, which occur when meeting under the tip of boulders or trunk breakage with collisions between its fragments, which is accompanied by a characteristic rumble.

Underestimation of the magnitude of pile failure and an erroneous idea of achieving the required bearing capacity of the pile on the ground during its immersion by pile-cutting equipment is often associated with its insufficient capacity (wear). To assess the resistance of soils during dynamic tests of piles, they must be immersed in the free fall of the hammer, and necessarily after the required period of "rest", i.e. the time interval after clogging, based on the characteristics of engineering and geological conditions and the above phenomena caused by them.

An important reason for incomplete immersion of prismatic driving piles is the irrational distribution of the shock pulse along their trunks. In this case, energy is spent on destroying the head and overcoming compression resistance along a large area of the lateral surface when the barrel is deflected due to an unbalanced impact, and a very weakened impulse reaches the tip. At the same time, pyramidal piles can be driven to the design depths, since the conical longitudinal profile of their trunks is linked to the distribution of shock momentum and soil resistance along them. Unfortunately, the use of pyramidal driving piles has been unfairly curtailed in the geotechnical practice of Belarus recently, despite the fact that they are the most rational and economical in terms of their indicators [3,4].

It should also be taken into account that unreliable initial data on the properties of soils and their variability in depth and in terms can also affect the unjustified determination of the design lengths of piles and the possibilities of their full and partial immersion.

Vibration immersion of piles in any soil is more effective in comparison with shock. Static tests of piles provide the most reliable data on the bearing capacity and deformability of their bases. However, problems also arise when conducting such tests. It is important to choose a test scheme and a loading system to transfer efforts to your own.

The scheme of testing piles for horizontal loads is very simple when the force is transmitted in the form of a strut to two adjacent piles using a jack. For the most common pile indentation and pull-out tests, a stop for the loading jack is required so that the pile under test is not affected. Most often, a beam is used, which, when the pile is pressed in, is attached at its ends to anchors (screw or pile) of the required bearing capacity for pulling out, and when pulling out the pile, the ends of the beam are placed on supports. The insufficient resistance of the anchors to pulling out does not allow creating the required pressing force on the pile and revealing the true bearing capacity and deformability of its base. It is not always possible to exclude the influence of adjacent anchors or supports on the tested piles when they are pressed or pulled out, which leads to distortion of the results and their unrepresentability.

Serious shortcomings arise due to the fact that in the vast majority of cases the requirements of clause 8.2.4 of GOST 5696-94 "Soils. Methods of field testing with piles", especially with regard to bringing the test load on the pile to a value at which the total draft of the pile is at least 40 mm. Most often, tests of piles, especially with high bearing capacity, are stopped due to the limited load capacity of the thrust system or when the load is brought only to the design effort, when the soil resistance is not exhausted even for shear along the trunk, and under the tip it remains unknown. This entails irrational solutions to pile foundations.

Research results and discussion. ***Saving on the number of tests does not justify itself and is even dangerous.*** With limited experimental data and serious discrepancies in the results obtained, there is a risk of an emergency situation from overestimation of the load-bearing capacity or uneconomical if it is underestimated. Unfortunately, this circumstance is not clearly reflected in the regulatory documents in force in our country. This situation needs to be corrected in the upcoming processing in accordance with the new legislation.

The manifestation of negative friction along the pile trunks is traditionally not taken into account when interpreting the results of their tests, which leads to an overestimation of the bearing capacity. Due to the more accelerated immersion of the pile pressed during the test in comparison with the subsidence of the soil along the trunk segment, all friction manifests itself as positive. The need in connection with these double deduction of negative friction forces from the pile test results is so far stipulated only in the manual 13-01 to the National Security Council 5.01.01-99 "Design and installation of bored piles", but this rule should apply to any other piles with a constant cross-section of the trunks. Negative friction does not occur only with pyramidal or conical pile trunks.

Pile tests are performed, as a rule, already during the construction period before the start of zero-cycle work, and when designing for a preliminary assessment of the bearing capacity of piles, it is calculated using tabular values of calculated soil resistances given in current regulatory documents, or based on the results of sounding in specific geological conditions. Despite the presence of engineering and geological surveys in the materials, the results of sounding are unreasonably rarely used in the design of piles. Apparently, this is due to the complexity of generalizing the probing indicators and the insufficiently reliable correlation between them and the values of the bearing capacity of piles. Further research is required to eliminate this gap [5-7].

Unfortunately, the developments and research of Belarusian scientists who justified the use of mace-shaped and hollow composite piles are unfairly forgotten and not used.

The variety of soil conditions, the nature of the strata and the tasks to be solved dictate the need to use various structural and technological solutions of piles, which are aimed at improving national regulatory documents based on the latest scientific developments.

In recent decades, at the initiative of scientists of the BNTU and the UP "BelNIIS Institute", progressive pyramidal driven and conical drilling and vibration-driven piles have been used, which have the most rational interaction with the soil base and the highest economic indicators. The proposed UE "Institute of BelNIIS", stamped in the ground and concreted, along with short conical piles of small diameter, are very effective.

To take advantage of the advantages of displacement to the sides and soil crimping, piles are increasingly used in stamped wells and boreholes. Telescopic shafts with enlarged sections at the top and widening under the lower ends, created by injection and crimping of soil in the face, allow ensuring the equal strength of the pile and base material. The spacer effect of wedge-shaped piles with a rebound under the widening of the lower ends makes it possible to reduce the length of the trunks and the compression boundaries, and eliminate negative friction. This is especially important in the presence of saturated weak and biogenic soils at depth, the cutting of which is fraught with air access to them and decomposition with intensive deterioration of strength and reformative properties.

In recent years, packed piles have become popular, arranged with displacement to the sides and compression of the soil due to vibration immersion of casing pipes with lost caps at the lower ends or conical punches (Figs. 6 and 7) [6].

According to the developments of the staff of our department, a very fruitful idea is being successfully implemented to increase the efficiency of pile foundations by including grillages in interaction with the soil, especially when ramming dry concrete mixture under their soles or by injecting soil crimping. The dry concrete mix drains plastic clay soils, which significantly improves their properties and increases the bearing capacity of the base.

When concreting pile trunks in watered soils, the ascending mortar method proposed by Prof. I.N.Akhverdov is especially effective, when the casing pipe immersed with a heated shoe is filled with crushed stone, into which the solution is pumped from bottom to top as the pipe is extracted.

a) b)

a - immersion of a casing pipe with a lost tip into a water-saturated soil using an ABI machine with a vibrator on a guide rod; b - concreting of the pile shaft

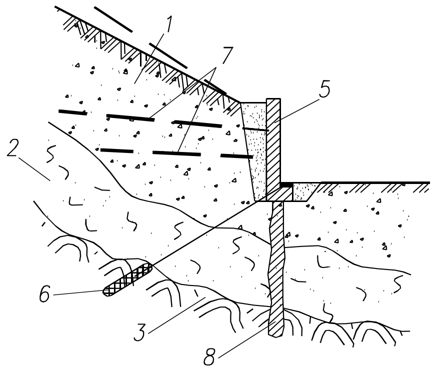
Fig. 6. Drilling piles arrangement

a)

b)

Fig.7. Immersion of a steel punch with a suspended vibrator when performing a bored pile (a) and a general view of the excavated stamped heel (b)

Pile underground walls, which can be arranged in a variety of soils, regardless of the degree of their water saturation, are used in quite large volumes in the construction of fences of deep pits and high retaining walls, as well as as part of anti-landslide structures (Fig.8). At the same time, when drilling piles with traditional technologies, problems arise associated with the occurrence of loose sediment (sludge) at the bottom of wells when drilling with an auger, as well as with softening of the water-saturated soil surrounding the pile under water pressure due to the difference in its levels outside and inside the well, even when it is drilled under the protection of the casing pipe. This leads to an underestimation of the bearing capacity of the piles due to the low compression resistance under the lower ends. For example, as a result of testing one of the piles made in water-saturated soils using traditional technology in a pit for a high-rise building on the site of the former cafe Rechenka along the ave. Thus, its bearing capacity on the ground of only 750 kN was achieved. By improving the technology of pile construction using vibration penetration of the casing pipe with the appearance of compacted sand plug at the bottom of it. Its height during excavation at the upstream length was left sufficient to exclude extrusion under water pressure. The subsequent vibrational immersion of the inner pipe with the lower end plugged with a lid made it possible to stamp the heels out of compressed sand and, due to the presence of the required amount of cargo, transfer the test pressing forces to the piles up to 2700 kN. At the same time, the total precipitation of the six experimental piles ranged from 16.5 to 24.5 mm, and they increased almost linearly with increasing pressure loads [7].



1 – landslide soil; 2 – weathered rock; 3 – solid rock; 5 – combined pile raft Foundation; 6 – CFA prestressed anchors; 7 – drains; 8 – piles

Fig. 8. The scheme of the anchored anti-landslide pile grillage

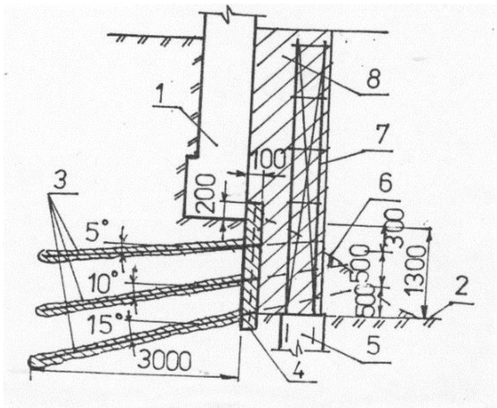
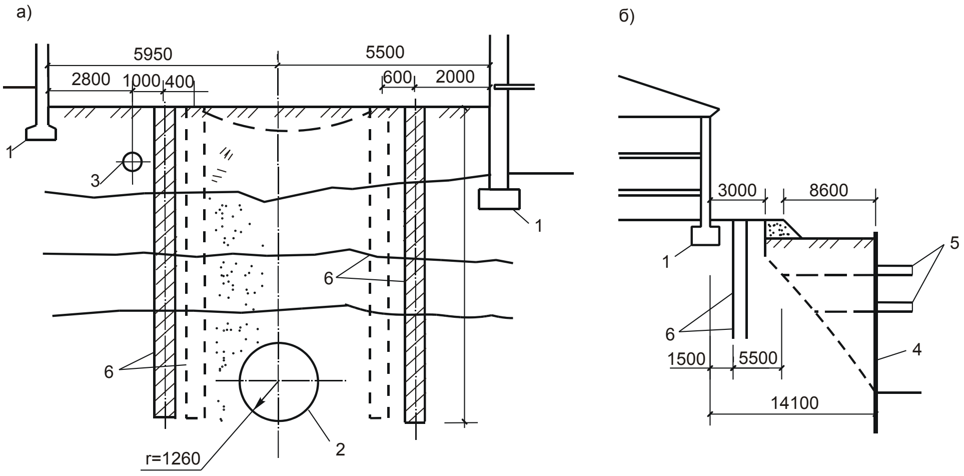


Fig. 9. Nagel fasteners under the foundations of the house near the excavation of the Kupalovskaya metro station

In recent decades, drilling injection technology has been widely used in the geotechnical practice of Belarus when performing piles, which makes it possible to strengthen the foundation of piles and successfully solve important tasks during the construction and reconstruction of many facilities. In geotechnical reconstructions, soil reinforcement with horizontal, vertical and inclined reinforcing elements in the form of piles is increasingly used. For the first time, the nagel method of soil reinforcement was used when excavating the soil below the foundations of the building near the pit of the Kupalovskaya metro station (Fig. 9). Later, the nagel fastening of the slopes was applied to the pits for the garages of Atlant OJSC and the underground shopping center on Independence Square in Minsk.

Drilling piles are used to prevent uneven foundation deposits and excessive deformations of existing buildings and structures from mining operations near them. Cut-off pile walls limit the areas of soil collapse at underground workings or ditches near existing buildings (Fig.10).

The effect of such structures is manifested in the formation, creation of anisotropy of soil properties and obstacles in the way of wave effects of noise and vibration in the soil. They dissect and extinguish waves, especially if rubber waste, granular polystyrene foam or other viscoelastic materials are added to wells.



1 – foundations; 2 – tunnel; 3 – pipeline; 4 – enclosing wall; 5 – tubular spacers; 6 – piles of a cut-off structure.

a) tunneling between college buildings; b) construction of the excavation of the Oktyabrskaya metro station near the museum

Fig. 10. Examples of the installation of cut-off structures from pile walls during mining operations near existing buildings in Minsk

Drilling injection technology makes it possible to strengthen foundations and foundations more effectively in comparison with traditional methods during geotechnical reconstructions (Figs. 11 and 12), providing cost-effectiveness and social effect, the ability to work in cramped conditions of objects without dynamic effects on them, with a low specific consumption of materials and labor costs at sufficiently high construction rates.

a) b)

a) during the reconstruction of a residential building on Penzenskaya Street in Minsk; b) general view of the house after reconstruction

Fig. 11. Work on the installation of bored piles with injection heels and cementation hardening of soils at the base of existing foundations

a) b)

Fig. 12. Work on strengthening the soils at the base of the pile foundations of the Holy Ascension Church in Borisov with the help of drilling piles (on the lower the image shows a small-sized drilling rig in the process of drilling wells)

Sinking of wells by erosion of soil under water pressure was applied in 1982 when installing drilling piles and strengthening loose sand lenses at the base of foundations at a number of facilities. More advanced techniques of inkjet technology have become possible thanks to the purchase of special imported equipment. The development of this technology began with the construction of piles with a diameter of up to 80 cm to a depth of up to 25 m for the end support on the slope of the ski slope in Silichi (Fig. 13), and then it began to be used in solving other geotechnical tasks at other facilities (Fig. 14).

Fig. 13. Piles made using jet technology for the end support on the slope of the ski slope in Silichi

Fig. 14. A fragment of a wall made of pillars made by jet cementation in blocked soils for fencing a pit for a high-rise building near the Romashka store in Minsk

Conclusion. The variety of engineering-geological and hydro geological conditions during the construction and reconstruction of various facilities dictates the need to apply various structural and technological solutions of pile foundations to the geotechnical practice of Belarus. Problems in the design, execution and testing of piles are caused by miscalculations in determining their bearing capacity, imperfection of the requirements of existing national regulatory documents, insufficient completeness of initial data on the characteristics of the nature of stratifications with variability of soil properties in the base in depth and in plan, violations of the pile testing methodology and incorrect interpretation of the pile test results obtained, especially when negative friction along the trunks, incorrect techniques when submerging finished and installing packed piles in unstable and water-saturated soils.

The following measures will solve these problems:

To immerse the driven piles into the bearing layers of the soil at the design depths, a washout or lead wells should be used, which will also reduce the level of dynamic impacts on adjacent structures and underground utilities. It is advisable to actively apply an effective vibration method of immersion of finished piles or casing pipes for packed piles, especially using resonant vibration loaders with a minimum level of dynamic effects in the transverse direction.

The pile testing procedure and the requirements of clause 8.2.4 of GOST 5696-94 "Soils" should be strictly observed. Methods of field test with piles", especially with regard to bringing the test load on the pile to a value at which the total draft of the pile is at least 40 mm.

When processing existing regulatory documents for the design and installation of all types of piles, the requirements for the number of piles to be tested should be more clearly specified to ensure the reliability of the results obtained. If they are interpreted for all types of piles in the presence of negative friction along trunks with a constant cross-section, it follows from the obtained values of the pressing test loads to subtract a double fraction of the forces of such friction.

To eliminate negative friction, preference should be given to the wedge-shaped shape of the pile trunks, which, in combination with stamped widened heels and crimping under the grillages, will increase the bearing capacity and efficiency of pile foundations.

In the executive documentation for hammered and bored piles, it is necessary to indicate the depths of their immersion, as well as the magnitude of failures during hammering or vibration immersion and their comparison with the values obtained during control dynamic tests after the required rest with a free fall of a hammer with a known weight and drop height.

When drilling wells for packed piles, it is necessary to clean the bottom of the sludge or press it with heel stamping, and in water-saturated soils, additionally exclude filtration softening of the surrounding soil by topping up the water in the pipe to a level exceeding the groundwater mark. Preference should be given to methods of drilling wells with displacement of soil.

When assessing the bearing capacity of piles in specific engineering-geological and hydro geological conditions at the design stage, static and dynamic sounding data should be used more actively, and to increase the reliability of the results obtained, deeper research is required to obtain reasonable correlation dependencies for various types of soils and their conditions.

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М.И. Никитенко[1], В.Ю. Журавский[2]

[1]Беларусь ұлттық техникалық университеті, Минск қ., Беларусь
[2]Главгосстройэкспертиза, Минск қ., Беларусь

БЕЛАРУСЬ ГЕОТЕХНИКАЛЫҚ ТӘЖІРИБЕСІНДЕГІ ҚАДАЛАР ІРГЕТАСТАРЫНЫҢ МӘСЕЛЕЛЕРІ

Аңдатпа. Беларуссияның геотехникалық тәжірибесінде қадаларды жобалау, орналастыру және сынау кезінде туындайтын кейбір мәселелер келтірілген, оларды шешу мүмкіндіктері көрсетілген. Қадалардың іргетастарының тиімділігін арттыру бойынша ұсыныстар беріледі.

Тірек сөздер: қадалар, геотехникалық тәжірибеде, қадалар, қадалар.

М.И. Никитенко[1], В.Ю. Журавский[2]

[1]Белорусский национальный технический университет, Минск, Беларусь
[2]Главгосстройэкспертиза, Минск қ., Беларусь

ПРОБЛЕМЫ СВАЙНЫХ ФУНДАМЕНТОВ В ГЕОТЕХНИЧЕСКОЙ ПРАКТИКЕ БЕЛАРУСИ

Аннотация. Приведены ряд проблем, возникающие при проектировании, устройстве и испытаниях свай в геотехнической практике Беларуси, изложены возможности их решения. Даются рекомендации по повышению эффективности свайных фундаментов.

Ключевые слова: свай, в геотехнической практике, забивные сваи, свайных фундаментов.