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Main Properties of Pile Installation and Influence of Various Piles with Soils

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Abstract: In Belarussian geotechnical practice, there are often problems in the design, installation and testing of piles. These problems arise from incorrect knowledge of how piles interact with different soils. In this study, the researcher propose solutions to such problems for improving the efficiency of pile foundations. The practical experience accumulated in the Republic of Belarus can also be useful for Iraq where similar ground conditions occur during construction.

Key words: Jacking, interaction, uplifting, geotechnics, soil, construction, load, foundation, shear, pile, compression, resistance, technology, foundation

INTRODUCTION

Piles are the oldest types of foundations which primitive men driving in the bottom of reservoirs while building their dwellings on the water. They are a kind of long and slender structural foundations used to transmit foundation loads through soils of low bearing capacity to deeper strata having high bearing capacity, however, there may be weak soils on the surface or at a depth at the same time. Pile foundations are used in construction and reconstruction which carried in difficult geological conditions are used in the construction of multi-story buildings as well.

Nowadays, there are many kinds of pile designs and technologies. In the technical literatures and codes, pile classification according to various characteristics is described such as the composition of the pile foundation, the shape of the pile in longitudinal and transverse study, the method of installation and the methods of their construction.

Clearly, piles can transfer to the ground various loads as vertical compression or uplifting as well as lateral and moment forces. In this regard, it is important to know how different piles interact with different soils. Understanding such features and making the right decision on the design of the piles based on the dynamics and kinematics of the force effects will help to avoid many of the errors encountered-avoid many mistakes and problems when constructing them. This study shows the features of the pile behavior under axial load. The research is based on the practical experience of the reseracher.

PILE BE DRIVEN INTO THE GROUND (DRIVEN PILES)

Reinforced concrete piles are the most common piles. The features of their interaction with the soil will be considered according to two classification criteria. The soil can take (perceive or withstand) compressive and shearing stresses. In geotechnics, usually two types of piles are described depending on the manner in which the load is transmitted into the surrounding soil. In the first case, the important point is that the soil resistance is derived primarily from skin fraction or adhesion between the embedded surface of the pile and the surrounding soil. Such piles are often called “floating pile” but this definition does not show the essence of the interaction of these piles with soils. The ground surrounds the piles, around the perimeter and prevents their bending from contraction. Also, it wouldn’t be true to be called such piles “friction piles”. Friction piles have soil resistance only along the surface of piles body while more important is the resistance of the ground below the lower end of the pile. Proceeding from this, the normative literatures of the Republic of Belarus and of most foreign countries use a more appropriate term “be captured piles by soil” in such

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piles. In the second case, the soil friction resistance at the pile tip. If there is no soil frictional resistance along the pile body and most of its carrying capacity is transferred to the relatively incompressible stratum below the lower ends of the piles then these piles are called end bearing piles.

Lapshin (1987) suggested to distinguish the following two important classification characteristics of any type of piles interaction with surrounding soils. These signs are based on the features of the piles installation:

- Piles are formed by displacing the soil around the piles shaft
- Making piles by driving cylindrical steel shell into the ground then excavating soil from it

The first case is characterized by installation precast concrete piles into the ground in different ways by driving, vibrating and by jacking. Also, the soil is displaced when concreting the cast-in-place piles which are formed by driving cylindrical steel shell into the ground and then filling the cavity of the shell by fluid concrete or by pipe piles which are usually driven with conical tip at the pile tip.

The second case is typical for piles which are formed in prebored holes in the ground and then concrete poured into the ready hole. As a result of this process, the soil is partially loosened on the walls and sludge is accumulated in the bottom of the boring hole.

There is an erroneous opinion about compacting the soil and about the physical processes taking place in this process when displacing. This opinion was refuted by Nikitenko with his students (TKP 45-5.01-45-2006) because when expanding the soil around the well, the compressive stresses are distributed in radial directions and promote the compression of the soil with a gradually decreasing intensity. In this case, along the circumferential directions, tensile stress causes repackaging of disconnected sandy particles and rupture cracks between connected clayey soils with decreasing their adhesion.

Impulsive dynamic effects on sandy soils during the pile driving and repackaging of particles contribution loosening in the upper layers with compaction at the lower ends but this effect does not appear in the cohesive soils in some depth. In piles with cylindrical cross sections the processes of compression and extension of the displaced soil in circumferential directions are distributed evenly along the contour but in rectangular sections with stress concentration at the angles, discontinuous cracks after installation of piles are possible at the surface even in sands (Fig. 1). In clayey soils, the particles are also repackaged in combinations of their compression and shear pressure but from the expansion, brittle fractures with a noticeable decrease in adhesion from the breakdown of structural bonds become more pronounced.

Fig. 1: Gap between sandy soil with rupturing cracks in the corners when the pile body is tilted from misaligned hammer impacts during pile driving

Fig. 2: Not be driven to design marks of piles

In recently years, in many countries, geotechnical practice was dominated by driven piles due to their rapid installation and the achievement of soil compaction when it was displaced around the pile shaft. But should not be forgotten about the significant drawbacks of such piles. Limited bearing capacity on the ground for small ranges of lengths and cross-sections of shafts, negative friction resistance along pile surfaces, harmful dynamic effects on adjacent objects during hammer striking in driving methods. Without leader holes or jetting's method (TKP 45-5.01-45-2006), precast piles could not be installed to design marks, especially in sands which inevitably causes the situation so-called "pile forests" (Fig. 2).

The process of cutting off protruding sections of piles is laborious and even dangerous. There was a case when even the helmet did not prevent the accident from blowing a piece over the worker's head.

To exclude such an entrenched, perverse practice, determined its causes. Workers cannot load the piles at the required depth, cut the upper parts of the piles and consider that the piles have plunged to the maximum possible depth and do not load any more when the hammer strikes. However, they do not take into account the possible interactions of piles with soils.

Commonly piles to not be loaded onto design depths when a thin solid layer of hard soil is encountered in the overlying the mass of the base in which the erroneous design failure value may be reached prematurely. In this case, the remaining thickness of such a hard layer during punching can be pierced during operation and then the lower end will be in a low-strength massif.

The amount of refusal (the term itself is unsuccessful), i.e., driving of piles from one hammer blow or 1 min of vibration can exposure because of pile's jamming into coarse sandy soil with dilatant unfolding particles in shear along the contact zone along the pile shaft, pile's slipping after the jamming is due to the rotation of soil particles because of contracting and a decreasing in the volume of the shear zone along the pile shaft with a decrease in soil resistance, pile's saponification, clayey soil becomes plastic and slippery like soap as the soil turns into a flowing state due to the transformation of the connected water into a free from shocks. Thus, the resistance to shear along the pile stem and under the lower end of the pile falls.

Pile's suction, whenpiles can themselves immersion into clay soils after the hammer blows have ceased. This occurs due to the appearance of a vacuum in the gap (empty space) under the lower end of the pile when lifting from the elastic deformations of the compressed pile shaft and surrounding soil, deceitful (low) refusal when pilecannot be driven at design depth due to air or water bubbles (trapped gases) which is formed at the end of the pile because of poorly filtering of fine and silty sands with large elastic strains from impact pulses, piledancing when piles can sink very abruptly, speeding up and slowing down their immersion. This happens due to existing a boulder (big stone) under the tip of the pile or the pile shaft breaks. This process is accompanied by a characteristic roar (noise).

Small values of pile be driven from one strike of a hammer or one minute of vibration and an erroneous idea of the achievement of the required soil resistance are due to insufficient capacity (deterioration) of the equipment. To properly assess the resistance of the soil, piles must be immersed with hammer blows or a vibrator without excess weight and make a break between impacts for a certain period of time. Also, during dynamic tests, should be paid attention to the behavior of piles and their interaction with soils.

One of the reasons of not thoroughly driving of piles are is not the unsustainable distribution of the momentum from the impact (impact pulse) along the body of the piles. The energy of the impact pulse is expended on destroying the pile head and resisting ground pressure because of the large area of the lateral surface of the inclined pile shaft. This is due to a non-axial impact and therefore a very weak impulse reaches the end of the pile. Simultaneously, piles with the form of a pyramid are immersed (struck or hammered) to the design depth much better if the cross section of their shaft is reduced in proportion to the shock impulse and increase in soil resistance with increasing depth. Unfortunately, recently in the geotechnical practice of Belarus stopped using driven piles in the form of tapered, although, these piles are more rational and economical in comparison with straight piles. Also, Belarus does not use piles in the form of belled drilled shaft and straight driven piles which consist of hollow elements. Piles, the end of which in the form of a tapered very well take pulling forces in the case when they are installed as end bearing piles. Piles consisting of several empty elements can be used with an unsustainable surface of the ground and it is easy to immerse the lower ends of the piles to the desired projected depth. The disadvantage of these piles is that they cannot bear pulling, shear and moment loads. Important advantages of tapered piles are:

- Absence of friction along the shaft of the pile
- The soil is compressed along the entire length of the pile shaft with the inclination of the pile faces in a larger proportion
- Ower metal consumption for reinforcement, especially pile heads with increased cross-section
- it is possible to drive pile to the necessary design marks, since, the cross sections are compared with the distribution of impact pulses when the piles are driven

Practical experience shows that in any soil the immersion of driven piles by means of vibration is more effective than piling with strike. This is due to the fact that the vibration effects on the pile occur continuously. When the piles are pierced with shocks, the pulses alternate with each other at short intervals. When vibrating the soil particles along the trunks of the piles and with each other under the pile tip, they stop resisting piling the pile into the borehole due to the lubrication with water. The water shakes under the influence of vibration and passes from the connected state to the free statement and after the cessation of shaking the structural water colloidal bonds on the surfaces of the soil particles are restored as well as the general resistance of the soil around the piles.

To the precast piles relating the precast piles, piles in the form of metal pipes with screw blades at the end of the piles. They are driven with excavating of soil from the well. These piles are mainly used for coaxial indentations and pulling forces which are held by compressive forces in the ground below or above the pile blades.

REINFORCED CONCRETE DRILLED PILES (CAST IN PLACE PILES)

The use of bored piles has many design and technological solutions as there are many different types of soil, many options for soil layers and construction purposes. Modern scientific developments offer several types of bored piles.

Bored reinforced concrete piles with cylindrical shafts are the most common used piles. Such piles are created with the help of concrete in boreholes while the soil can be extracted from the well or displaced to the sides. The body of such piles can be reinforced (fixed) along the entire length of the body of the piles or only the upper part of the pile's body. This reinforcement process depends on how the driven or pulling forces act with shear and moment forces. The characteristics of the ground and its features also affect the process of reinforcing the piles. Pile reinforcement does not apply only in the absence of bending deformations. Only in this case piles can be hollowed and have a solid study. But when there are under shear and moment loads such piles may collapse. An example of the failure of prefabricated, hollow piles of reinforced concrete can be the case that occurred in China on June 27, 2009 (Anonymous, 2009). The 13 story residential building fell due to digging excavation for an underground garage on one side of the building and deputing the soil on the other side of the building along the river bank (Fig. 3).

The technology of the construction of bored piles without displacement and compression of the surrounding soil (Anonymous, 2002a, b) is the simplest. With this technology, a bore hole is drilled then reinforcement cage is placed and the concrete is poured. The shaft can be drilled with a conventional auger in the presence of strong soil. However, in the case of crumbling or unstable soils, it is necessary to protect the well with a casing or to using bentonite suspension during drilling. If the wells are very deep, the concrete is poured into the well with the help of a special pipe. From this pipe, the concrete leaves through the lower end and rises upwards in the space between the pile (casing) and the walls of the bore hole. If the diameter of the well is small and does not allow the immersion pipe to be immersed in it it is necessary to feed the concrete through the casing or pump it through the hose of the concrete pump to the bottom of the well.

(a)

(b)

Fig. 3a, b: Collapsed in Shanghai, a 13 storey residential building (Anonymous, 2009) in the failure of prefabricated hollow reinforced concrete piles, weakly reinforced by tensile rods of small diameters

Professer Akhverdov proposed a method for piles in saturated soils or restricted conditions of objects. This method consists in the fact that the casing is initially installed with the lost bottom plate being filled with stone. The grout is pumped upwards through the injector from the bottom upwards and the casing is gradually removed. If driving bored piles are carried out in traditional ways, then problems can arise. Such problems include the occurrence of loose sediment (sludge) at the site of wells when they are drilled with auger. Also, the strength of the water-saturated soil that surrounds the pile can be destroyed. This destruction occurs under the pressure of water due to the difference in water levels outside and inside the well when it moves under the protection of the casing with an open bottom end. This leads to an underestimation of the bearing capacity of the pile bases due to the low resistance of the soils to compression under the lower ends. For example, we will give the results of tests in a foundation pit for the construction of a high-rise building at the site of the former cafe "Recenka" at Pobediteley Avenue, Minsk (Belarus). Thus, testing of one of the piles in water-saturated sands (with extraction

Fig. 4: Structure of bored piles in saturated sands on the left-installation the bailer for excavating from the casing of biogenic soils over the compacted ground plug to the right-its displacement by a second pipe with closed end

of sand from the well) showed the value of bearing capacity on the ground of only 750 kN. Therefore, it was proposed to improve the technology of the device piles by vibrating the casing with the emergence of a condensed sand plug at the bottom (Fig. 4).

Further, the upper ground layers of soil were removed from the casing. At the same time, the water pressure could not remove the sand plug. Then the inner tube with the closed end was installed by vibrohammer. This action allowed to remove the sand plug and transfer pressure to the pile up to 2700 kN. At the same time in six experimental piles, the total settlement was from 16.5-24.5 mm with a linear increase in the transmitted loads.

Serious problems can arise during the construction of piles at great depths and large diameters of pile's shaft in saturated sands. Especially, when in the ground there is pure pressure between clay layers. This happened in the foundation pit for the construction of the high-rise building of Gazprom in Minsk (Belarus).

There, bored piles Ø 0.118 m were immersed in a carrier layer to a depth of up to 29.5 m.Wells were drilled using casing pipes with open lower ends. The ground from the pipes was removed by sludge-bailer (Fig. 5), since, the pressure water was between two layers of morainic sandy loam. Water was also added to the casing as described in the manual (Anonymous, 2002a, b). For concrete piling of the piles under the water (Fig. 6), the method of the vertically moving pipe (VPT method) was used. But this affected the fact that the quality of the concrete at the top of the piles was very poor (Fig. 7).

Fig. 5: Drilling of wells by drilling rigs of the firms "Bauer" and "Cassagrande" under the protection of casing pipes with scooping out of the ground by bailers and refilling of water into the casing

Fig. 6: Concreting of piles in a casing filled with water by the method of VPT when pouring concrete from a mixer through the socket of a concrete pipe

This situation was influenced by factors that were not taken into account: the water that filled the casing contained pieces of clay soil. A concrete mix for the construction of barrel piles was used with a cone draft of more than 18 cm. This is indicated in the VPT method. However, concrete poured out through the lower end of the pipe and mixed inside the well with water that contained clay. This greatly worsened the quality of concrete (or concrete mix) . When leaving the end face of a concrete pipe into a wide gap between the casing, a highly liquefied and contaminated concrete mixture captured clayey sludge containing clumps of uncooked completely sandy loam of moraine and clayed sand, taking them upwards inside themselves under a head, faster by contact filtration outside the concrete pipe when lagging along the inner surface of the casing.

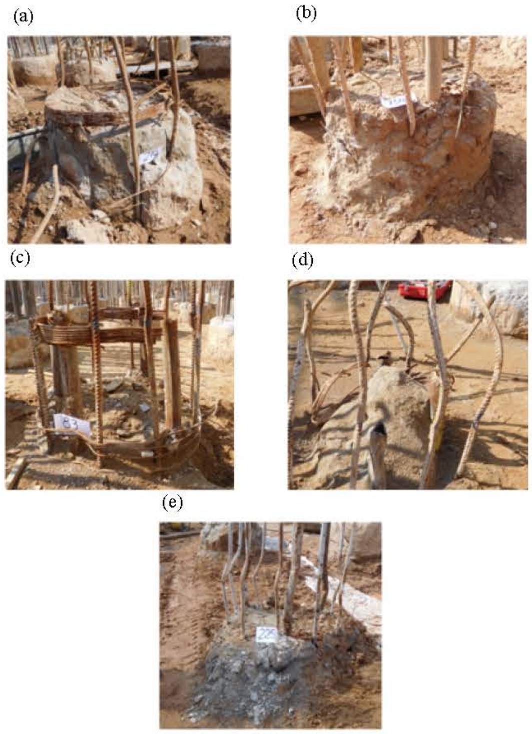

Fig. 7a-e: Defects of the heads of bored piles as a result of underwater concreting with cast concrete mixtures

The concrete mix was very heavily filled with sandy clay soil, especially to the top of the casing. Also, soil sludge from sandy clay was distributed unevenly throughout the length of the piles.

Inside the concrete piles there was a lot of rubbish from the sandy clay. This was determined when cutting off excess pile tops and found that the piles have strength lower than the defined design. Throughout the depths of the piles were drilled with a diamond tool and also found lots of sections of clay and sand. This problem greatly slowed down the construction of the facility.

Unfortunately, the proposal of one of the researcher of the study was not accepted. The researcher used an analogy both in the construction of trench walls (Anonymous, 2006). He proposed to combine the VLT method with the vibrational feeding of thick concrete mixtures (with a cone draft of only 5-8 cm). Such a method (Anonymous, 1975) provides the following at the lower end of the pipe through which concrete flows it is also attached from above (outside) the vibrator head (Fig. 8) when switching on the thick concrete mixture is liquefied.

Connected water in the concrete mixture on contact with the pipe passes into the state of free water and becomes a lubricant. This lubricant helps to bring concrete down to the end of the well without mixing with

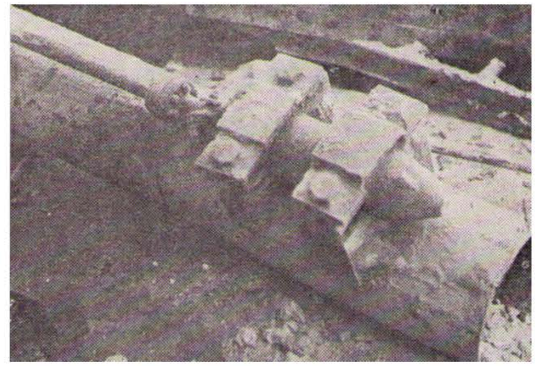

Fig. 8: Equipped with a vibrobullet bottom concrete pipe

clay soil particles (clay slurry) or with slurry. This solution also saves cement consumption up to 100-150 kg per 1 m 3 of concrete mix. The strength of concrete is preserved and the process of its hydration is accelerated.

Unitaryenterprise"Institute BelNIIS" proposed to use embossed in the ground and concreted grills together with conical piles of small size (Anonymous, 2006). Employees of the department proposed the idea of using grillage (TKP 45-5.01-254-2012, 2013) for soil compaction, solution pouring or pressure (tamped) under the soles of a dry concrete mix. Such a mixture drains plastic clay soils and improves their properties with an increase in the bearing capacity of the substrate.

To exploit the dignity that the soil is shifted to the sides and soil compaction, piles are poured into stamped holes (Anonymous, 2006) and bore injectors when injected into bore holes under the pressure of cement mortar (Anonymous, 2005) or cast concrete (Nikitenko, 2008, Nikitenko *et al*., 2013).

Grouted bored piles technology makes it possible to make the soil harder at the base of the piles with the help of soil compaction. The creation of broadening under the lower ends and along the trunks of the piles makes it possible to increase the total resistance of the soils. Also, used shut-off pile walls. They protect against uneven sediment and excessive deformations of existing buildings and structures. The pile walls limit the zones of caving in the underground excavations or pits near existing buildings (Fig. 4).

Such designs have a positive effect due to reinforcement, creating obstacles for wave influences of noise and vibration in the ground. In the ground, anisotropic properties are created that dissect and absorb waves. These properties are enhanced by adding rubber waste, granulated expanded polystyrene or other resilient materials to the wells.

Pile stems with enlarged sections at the top and widening under the lower ends of the piles ensure the same strength of the pile material and pile bases. Their models are created by injection and pressing the soil in the face. Piles in the form of a wedge expand the zone of compaction of the ground and their use allow to reduce the length of the trunks of piles, the boundaries of compression of the ground and eliminate negative friction. This is especially, important in the presence of weak and biogenic soils at depth. Since, air access to these soils can degrade the strength properties of the soil.

In recent years, pile piles have become very popular. These piles are built using casing pipes which are immersed in a vibrator. In the lower ends of the pipes, lids or conical punches are installed (Fig. 9).

The technology of vibrohammers for inserting piles includes penetration equipment borehole that helps to be driven steel casing pipes in the form of a conical or pipe with a special bottom plate, driving the reinforcement cage into it, filling the interior with concrete mixture (Fig. 10) and then pulling upward the casing at the same time using a vibrator for compacting concrete mixture and for and high quality formation of pile shaft in the hole (Fig. 11).

The advantages of bored-vibrating piles technology by driving cased shaft with losing the plate at the end are high speed and simplicity of operations. Ability to carrying-out the piles in different geological conditions, regardless of the ground water table due to the choice of rational methods of boring holes to concrete shafts and rammed vibrating concrete with expansion on their toes, high quality of concrete piles by vibration and filling the shaft with concrete mixes thus may have the best water cement ratio, good mobility and not rusting during interaction with groundwater.

The ability to assess the bearing capacity of piles according to TKP 45-5.01-254-2012 (2013) in designing depth by measuring the rejection value during driving the case with a vibrator with losing the plate on the end or ramming of the pedestal under the toe. Last advantage is letting to reveal undiscovered zones of weak soils between the exploratory excavations (boreholes and penetrating points) and promptly take the necessary steps to provide the perception of design loads on pile foundations and increase maintenance safety for over ground structures.

By drilling borehole through the filled and organic soils until bearing deposit, it is required excavation to prevent filling it into the pile toe. In such cases, the casing must dive with an open end. Weak organic soils removed by bailer and impacted the plug then pulled downward by means of the interior pipe with closed-end. Using this punch, we can extend the toe (Fig. 12) by filling the portions of dry concrete mix to outer casing pipe. The dry mix under the pile toe drains clay soils and improves their properties.

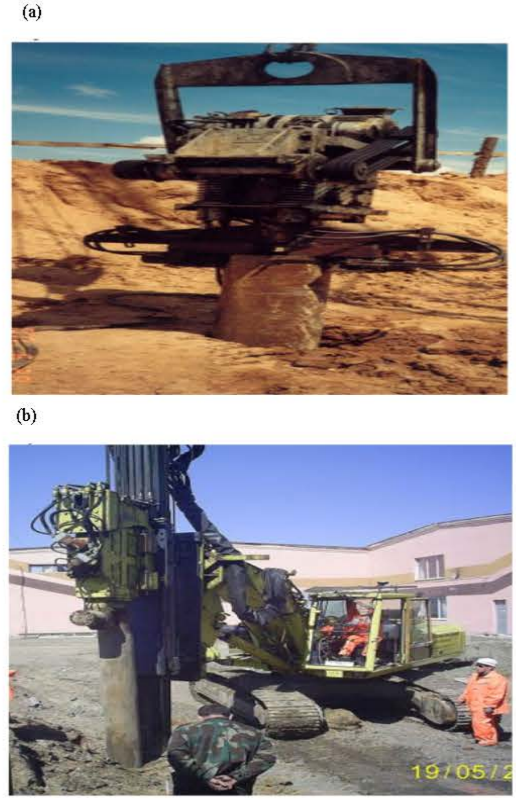

Fig. 9: Making holes for bored piles: a) Driving conical punch by using hanging vibratory and b) Driving cased shaft by vibrating on the hard track machine ABI

Fig. 10: Concreting of the casing shaft by mixer

If the inner tube is sharpened, the concrete mixture that is compacted by it will flow around the outer surface of the pipe when displaced and the resulting broadening

Fig. 11: Driving tapered casing by using hanging vibrohammer

Fig. 12: The cases-punch with butt plugged end and excavated rammed pedestal under the pile toe

will acquire a vertically elongated shape with a decrease in the transverse dimension. This was confirmed by the device of an experienced pile in the sand under a multifunctional building on the street. Timiryazev at the test of which the base load capacity was lowered by half compared to the design value. As can be seen from Fig. 12 at the flat end of the bottom plate of casing, the broadening appeared flattened with an increased diameter which ensured the achievement of the required ground resistance under the heel. It is enough simply to broaden the bottom ends of bored piles and along their trunks can be created by injection when injecting solution under pressure at an appropriate level.

In this case, the cement slurry drains excess water in the sands and quickly gains strength but in clay soils the hydration process is excessively prolonged and can last even several months without access to drainage air, worsening the properties of the surrounding soil due to its additional moistening. Therefore, it is preferable to pump the polymer mixture Uretek (Nikitenko, 2006) which is able to increase its volume several times by several times while creating a pressure for pressing the concrete mix of the pile shaft and the surrounding soil mass. In this case, this mixture hardens within 15-20 sec and gaining strength in 10-15 min without additional soil moistening.It should be noted that traditionally pierce shafts of piles with casted mixtures when immersed by vibrohammers after which with pipes, poured the cement although they are advisable to use more rigid ones which is especially important in saturated and clayey soils.

The advantages of technology of performance the bored-vibrations piles in weak clay soils in the presence of high levels of underground water were notably manifested on the project "cultural and wellness center and also hotel in the Novovilenskaya street and the Kanatnavo alley in Minsk" where one of the researcher performed scientific accompaniment of the zero cycle to research with correcting of design and technological solutions.

At the time of driving with vibrohammers the steel pipes with losing the plate on end of pipe to final depth was possible to predict the bearing capacity of the soil at the tip of the pile (Nikitenko *et al*., 2013) by the value of rejection, i.e., pipe settlement in meter per minute by vibratory influence at a known mass and the forcing frequency (equivalent calculated energy).

Even in the time of the lack of enough bearing capacity at the projecting depth we could refuse to continue more driving steel pipes (cased shaft) and increase the overall resistance of the soil due to the ramming of the pedestal under the toe. To do this it was enough to fill at about meter interval by dry (zero slumps) concrete mix in a cased shaft cavity and ramming it out of the casing base about half meter to produce an adequate-sized base enlargement until to get the rejection value of the project according to TKP 45-5.01-45-2006 (2006).

Since, at the time of boring the wells have measured the rejection value from diving cased shaft with losing the plate at the end, it was possible to determine the value of bearing capacity of soil at the base of all the piles (there

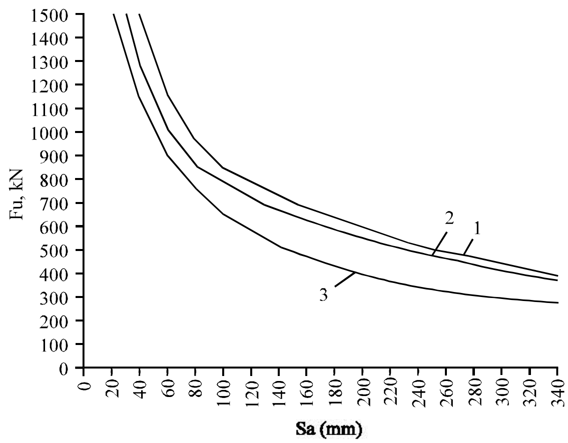

Fig. 13: Depending on the resistance of the soil failure F_u v. rejection of steel case Ø 426 mm lengths of 10 m with the pile point vibrator with theparameter, 1-m_1 = 4.0 ton Ппп E_d = 405 kN, 2-m_1 = 3.5 ton Ппп E_d = 310 kN, 3-m_1 = 2,5 ton Ппп E_d = 865 kN

were a few thousand in the object) and allowed them to load. To do this, the relevant calculations were performed and are plotted the soil resistivity by rejection value whilst driving the case shaft by using vibrators (Fig. 13).

Such method has allowed identifying several areas with low soil resistance which was not detected between the boreholes on lithological profiling according to the exploration. In these areas were taken the necessary measures to ensure the perception of design loads on pile caps. (M_1-Mass of vibrohammer, ton, t, E_d-Calculated energy of the vibrator, kN, determined from table (CTB 2242-2011, 2012), depending on the disturbing force).

By using Continues Flight Auger (CFA) technology in time of installation of bored piles with Italian equipment in all grounds helps compacting the surrounding soils of pile's shaft even in saturated soils wells are drilled with a continuous flight auger (Fig. 14a) through which with the lifting into the well is pumped under pressure from the grout mixer (Fig. 14b) and in it immediately reinforcement cage is immersed to the required depth. An important advantage of this technology is high-speed pile devices and compressing of soil under pressure along the shaft helps eliminate sliming and to achieve a higher bearing capacity of foundation (Fig. 14c).

Figure 14 equipment for piling CFA, a-drilling rig with a solid hollow auger, b-drilling rig for excavating of wells, c-lifting of the auger and installation with the vibrohammer after that installation the reinforcement cage The piles that are customized for this technology are called boron-pressed piles which are a type of grouted

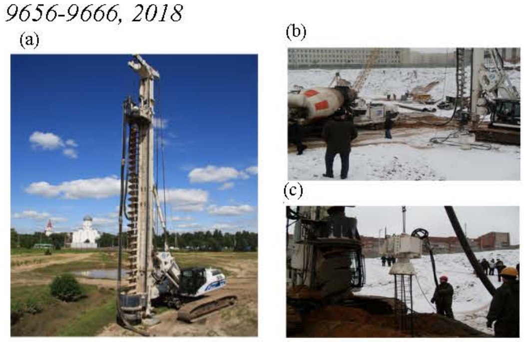

Fig. 14: Equipment for piling CFA: a) Drilling rig with a solid hollow auger; b) Drilling rig for excavating of wells and c) Lifting of the auger and installation with the vibrohammer after that installation the reinforcement cage

Fig. 15: Drilling rig for execution of the pile system CSP

bored pile (TKP 45-5.01-254-2012, 2013) and their interaction with soils when pressed is similar to other species arranged with displacement of soil in the sides.

When installing walls from intersecting trunks of piles or in the case of the need of their compact groups for the use of a similar technology of drilling and concreting, double drilling machines are used with a combination of casing pipes and a hollow auger along the CSP (Cased Secant Piles-Secant piles with casing) system inside them (Fig. 15).

The main disadvantage even with many advantages, of these two technologies (CFA and CSP) is the complexity of immersing large reinforcement cages in concrete filled wells by intensive drainage of the concrete mix in sands and rapid thickening. With this, retarders are required in the concrete mix which reduce the water loss and slow down their setting on the diving time of the reinforcement frames.

Fig. 16: Bayer displacement drilling system

When adjusting the flow rate of concrete and the generated pressure of its injection, it is possible to create broadening under the lower ends and along the length of the pile shaft and if necessary they can be tapered. The use of spreader (Fig. 16) will additionally displace concrete and soils in the walls of wells with their crimping, thereby creating even the required broadening and coaxial cavities which will save concrete consumption on the formation of shaft with an increase in the total resistance of the soils around the piles.

The drilling of wells with erosion of the ground under the head of water pressure was first used in Minsk in 1982 for the construction of brown pile piles, providing hardening of loose sand lenses at the base of foundations on a number of objects. More advanced methods of jet technology became possible due to the purchase of special imported equipment. (Fig. 17 and 18). According to this technology, piles Ø 0.8 m were made (Nikitenko, 2018) to a depth of up to 25 m for the terminal support of the lift on the slope of the ski slope in Silich (Fig. 17). Then it was used on other sites. This technology also makes it possible to create the required sizes and shapes of the piles by adjusting the parameters of the high-pressure injection (pressure, velocity of rotation and rotation of the monitor, flow rate) of the cement slurry but it is necessary to immerse the reinforcing cages after the creation of the piles with the inherent lack of this in the sands. More importantly, clay soils with mixing are not capable of gaining strength even after more than 6 months as it was in region Uruch'e.

In order to shorten the time of static tests of piles caused by a set of strength concrete, be asked to test steel pipes before their mass production from which the

Fig. 17: Piles for end support cableway liftsnowboard in silich by inject technology (in the background canbe seen the machine company (asagrande) to perform pile)

Fig. 18: The equipment of Italian company soilmec for inject technology

outer casing serves as a shifted trunk and the inner casing compresses the ground under the fifth pile (Fig. 19) with the tapered end. This eliminates the need in very large anchorages set-up test, it takes two times less load capacity of the loading hydraulic jack and separately it is possible to fix the soil resistances to shear along the trunks and compression under their lower ends. This approach is reflected by Anonymous (2002) as applied to the production of bored piles in place.

If there is a strong difference between one of the two types of soil resistance, it is necessary to load the casing or transfer the additional compression to the ground through the outboard side plates on the surface.

Fig. 19: Testing of piles on the principle of "pipe in a pipe"

CONCLUSION

There are many geological and hydrogeological features of the soil as well as many types of piles and the purposes of their application. Knowledge of the behavior and interaction of different piles with a variety of soils will allow us to make the right engineering decisions, avoid many problems and improve the efficiency of pile foundations for new buildings and reconstructed structures. The practical experience accumulated in the Republic of Belarus will also prove useful for Iran and Iraq where similar ground conditions are encountered in construction.

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