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Review Article

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Geotechnical Practice of Construction in Particularly Constrained Conditions

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ABSTRACT
Construction problems in cramped conditions of operating industrial enterprises are an important geotechnical task that requires a specific approach from civil engineers, especially from geotechnical specialists. At the same time, the presence of weak engineering and geological elements significantly complicates the implementation of geotechnical works. Any industrial enterprise carries out an update of its own production associated with the introduction of new technological lines or the construction of additional facilities. The use of bored and bored-injection piles with the combined use of soil anchors arranged using non-standard physical processes in most cases successfully solves many complex and atypical geotechnical problems. The article under consideration is a review.

Keywords: Geotechnical Construction, Electrohydraulic, Monolithic Reinforced Concrete Grillage, Bored Piles, Particularly Constrained Geotechnical Conditions, Ert Ground Anchors

The construction of buried structures in particularly cramped conditions of existing industrial production requires a specific approach from geotechnical engineers, who must demonstrate ingenuity and resourcefulness in the use of modern geotechnical technologies that ensure the safe operation of existing buildings both during construction and during the operation of a newly erected building or structure [1-15].

The working documentation "Complex for reception, storage and shipment of cement, completed by Technostroy, LLC "PKF" in 2016, involves the construction of a buried engineering structure 8.0 m deep from the existing relief level in particularly cramped conditions of industrial production of reinforced concrete structures and products for capital construction projects. The construction of the buried warehouse is carried out on the territory of the reinforced concrete structures plant ZhBK-1 at Lapsarsky proezd, 19 in the city of Cheboksary. Figure 1 shows the plan of the construction site, where in the immediate vicinity of the construction pit there are above-ground silo towers, a cement warehouse, an existing railway line, a concrete mixing unit and other buildings.

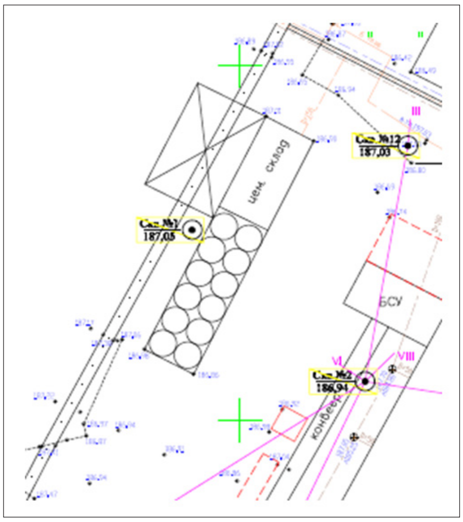

Figure 1: Extract from the general plan of the construction of the facility

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The complexity category of engineering and geological surveys according to the Technical Report, completed by Izyskatel LLC in 2020, agreement No. 3064 IGI dated 11.06.2020 is the second, established by a combination of factors that have the maximum impact on the volume and cost of engineering surveys in accordance with Appendix G SP 47.13330.2016 " SNiP 11-02-96 Engineering surveys for construction. Basic provisions." Level II. According to the geomorphological factor, the survey area is located within one geomorphological element – category I complexity; according to the geological factor, no more than four lithological layers have been identified – category II ; according to the hydrogeological factor, one consistent groundwater horizon has been identified – category I ; specific soils are of limited distribution and do not have a significant impact on the choice of design solutions – category II ; hazardous geological and engineering-geological processes are of limited distribution and do not have a significant impact on the choice of design solutions – category II ; man-made impacts do not have a significant impact on the choice of design solutions and the conduct of engineering-geological surveys – category II .

In the engineering-geological structure of the investigated area, in the process of drilling, experimental and laboratory studies to an explored depth of 10.2 m , the following were identified (from top to bottom): soil-vegetation layer (pQ IV), modern formations (tQ IV) technogenic soil, modern deluvial formations (dQ IV), Upper Quaternary formations of problematic genesis (prQ III), Middle Quaternary eluvial-deluvial deposits (edQ II) and native deposits of Permian age (P3t) , covered from above by a soil-vegetation layer up to 0.4 m thick .

Figure 2 shows a typical engineering-geological section of a capital construction site.

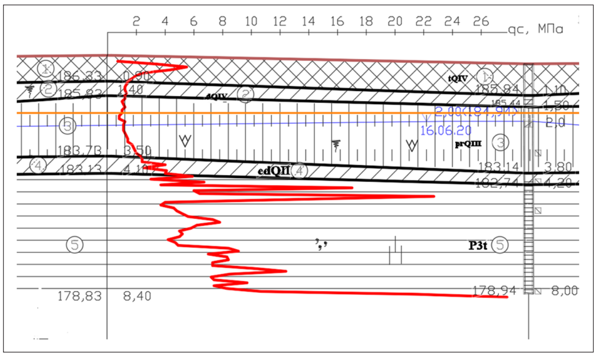

Figure 2: Engineering-geological section of the construction site

During the engineering and geological surveys (June 2020), the surveyed area is characterized by the presence of one groundwater level within the drilling depth (8.0 m). The depth of the established groundwater level from the earth's surface varies from 2.0 m to 4.1 m. The established water level mark on the surveyed site is 182.67 - 184.94 m.

The water-bearing soils are loess Upper Quaternary loams (IGE No. 3). The aquiclude is the underlying Upper Permian hard clays (IGE No. 5). The horizon is fed mainly by infiltration of atmospheric precipitation. Discharge is carried out in the valley of the river Shalmas.

In terms of chemical composition, the water is fresh, magnesium-calcium hydrocarbonate, hard, neutral in reaction (6.20-7.20 mg/dm3) in pH, non-aggressive in terms of aggressive carbon dioxide to concrete of normal permeability (W4) and moderately aggressive to metal structures.
In extreme natural situations (heavy rains, snowmelt), as well as possible leaks from water-bearing communications, the groundwater level may rise by 1.0-1.5 m (184.17 - 186.44 m) and/or perched water may form.

According to the conditions of formation and nature of distribution of groundwater, the survey area belongs to region II – B 1 potentially flooded as a result of man-made impacts (according to SP 11-105-97 "Part 1. Engineering and geological surveys", part II, appendix "I").

Taking into account all the above circumstances, including engineering-geological and hydrogeological conditions, as well as the presence of buildings in the immediate vicinity of the construction pit, bored piles with a diameter of 630.0 mm, secured with ERT soil anchors at two levels, are adopted as the most optimal option for fencing the construction pit. In this case, bored piles are adopted according to the bored-tangent scheme, united at the top by a monolithic reinforced concrete strapping belt (see Figures 3,4,5).

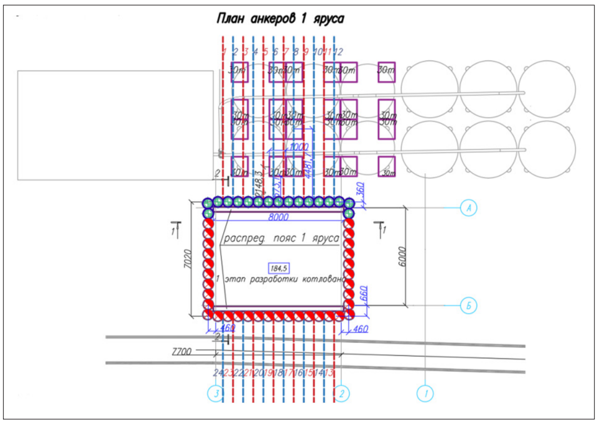

Figure 3: Plan of arrangement of buried retaining structures of the construction pit

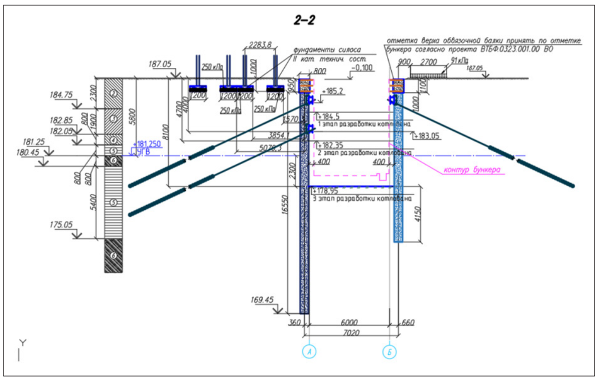

Figure 4: Scheme of vertical binding of buried retaining structures of the construction pit

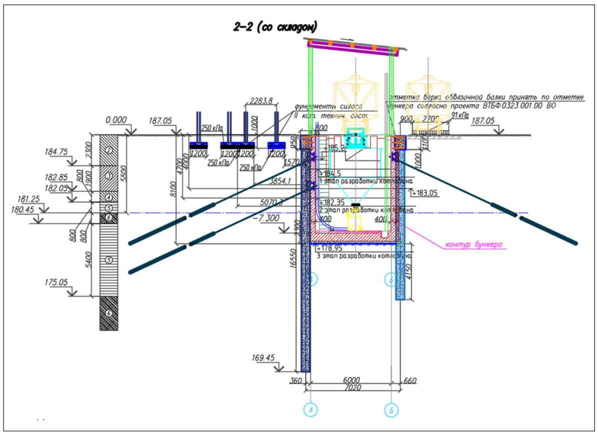

Figure 5: Scheme of vertical binding of buried retaining structures of the construction pit

Below in tables 1-8 are given the sequence of reinforcement of bored piles, the stages of geotechnical works, design of a ground anchor, the technological sequence of manufacturing a ground anchor ERT, the technology of forming a borehole by drilling in unstable soils, the technology of cementing a borehole of a ground anchor in unstable soils, the program of electric discharge treatment of a borehole filled with cement mortar.

Table 1: Sequence of Reinforcement of Bored Pile

1	Vertical piles of solid cross-section with a drilling diameter of 630.0 mm, are carried out under the protection of inventory casing pipes, reinforced to the full height with spatial reinforcement cages
2	Accepted marking of piles: SBN62.166 (length 16.55 m, drill diameter 620.0 mm), SBN62.112 (length 11.2 m, drill diameter 630.0 mm)
3	Anchoring (reinforcement release from the pile head) into a monolithic reinforced concrete grillage (tie belt) should be performed in accordance with the developed working drawings.
4	Sealing the pile cap (reinforced concrete cap) into a 50.0 mm reinforced concrete grillage (slab). 1. For piles, use heavy concrete of strength class B30 F 200 W8
5	Reinforcement of bored piles is provided for the entire length and is performed in separate sections from spatial welded frames. The frames are connected to each other by welding.
6	The longitudinal rods of the spatial reinforcement frame are: reinforcement with a diameter of 22.0 mm and 25.0 mm of class A500C. Transverse reinforcement of piles is taken from reinforcement with a diameter of 10.0 mm of class A240. In this case, the protective layer of concrete is not less than 40.0 mm
7	The rigidity of the spatial frame is provided by steel rings made of pipes with diameters of 406.4 mm and a wall thickness of 6.0 mm.
8	The rigidity of the spatial frame is provided by steel rings made of pipes with diameters of 406.4 mm and a wall thickness of 6.0 mm.
9	To ensure a protective layer of concrete, centralizers are provided from steel strips 20.0 mm wide and 4.0 mm thick in a quantity of at least 4 in one cross-section of the reinforcement frame with a step along the length of the frame of no more than 1.5 m.
10	Manual arc welding of spatial frame elements between themselves is carried out using electrodes of the E42A, E46A, E50A type.
11	For the production of spatial welded frames, it is prohibited to use reinforcement made of grade 35GS steel

During the construction of a retaining wall anchored with ERT soil anchors on two levels, the following must be strictly observed: stages of execution of geotechnical works, given in Table 2.

Table 2: Stages of Geotechnical Works

1	Site preparation, installation of fence piles and strapping beams
2	The first stage of soil development involves development up to the marks indicated in the corresponding sections, after the installation of piles for enclosing the excavation pit.
3	The first-tier anchors are installed after the first stage of soil development.
4	Pre-tensioning of anchors is carried out in accordance with VSN 506-88 " Design and installation of ground anchors"
5	The second stage of development involves excavation of soil to the design marks of the second-tier soil anchors. The order of works on the installation of soil anchors is similar to the works of the first stage.
6	The third stage involves finishing the soil to the design marks of the bottom of the pit.
7	The excavation of the soil should only begin when the strength of the erected structure meets the requirements of this project.
8	During the period before the start of the installation of sheet pile walling and for at least one year after the completion of construction, conduct geotechnical monitoring of the surrounding buildings
9	During the construction of structures below the zero mark of the retaining wall, dynamic and vibration effects are not allowed.

Table 3: ERT Soil Anchor

1	Anchor fastening structures: ERT ground anchors, parts for fastening the support of a ground anchor
2	Calculated load on ground anchor P w
3	The free length of the ground anchor is determined by the collapse prism of the excavation wall, the shape of which is determined by calculating the overall stability of the structure using the logarithmic spiral method.
4	Accepted marking of ground anchors: AG-15/8 (full anchor length 15.0 m, root length 8.0 m)

5	The drilling diameter for ground anchors is 150.0 mm, performed at an angle of 20-30 degrees to the horizon (according to the project)

Table 4: Ground Anchor Design ERT

1	For ground anchors, use cement mortars with a water-cement ratio (by weight) of W: C = 0.5:1
2	For cement mortars, use Portland cement without mineral additives of a strength grade not lower than M500
3	The use of pozzolanic, aluminous and slag Portland cements is not permitted.
4	Water for cement mortars, tap and technical, not containing sugars and phenols more than 10.0 mg/l , oil products and fats. Hydrogen index (pH) from 4.0 to 12.5
5	As an anchor rod, rod reinforcement with a diameter of 36 mm of class A500C (in a plastic casing with a diameter of at least 90.0 mm) and screw reinforcement with a diameter of 25.0 of class At800 are used.
6	For centering in the well along the entire length of the rod, clamps are provided (step no more than 2.0 m) made of sections of plastic pipes with longitudinal cuts along the perimeter
7	It is prohibited to use reinforcement made of grade 35GS steel for the production of welded frames.
8	Manual arc welding of anchor frame elements is carried out using electrodes of the E42A, E46A, E50A type
9	Parts for fastening the support of the ground anchor to the distribution plate (plate): spherical, conical and oblique washers (St45), lock nut (St3)

Table 5: Technological Sequence of Manufacturing the ERT Ground Anchor

1	The technological sequence for the production of bored piles in unstable soils includes the following operations:	
	1.1	Formation of a well of the required depth and diameter by drilling with continuous hollow augers
	1.2	Cementation of a well with cement mortar with simultaneous slow lifting of the auger and control of the solution supply into the well
	1.3	Electrical discharge treatment of a well at the root level
	1.4	Installing the anchor frame in the design position
2	The technological sequence for the production of ground anchors in stable soils includes the following operations:	
	2.1	Formation of a well of the required depth and diameter using auger drilling
	2.2	Filling the wellhead with cement mortar
	2.3	Electrical discharge treatment of a well at the root level
	2.4	Installing the anchor frame in the design position
3	When installing ERT ground anchors, the subsequent well must be installed no less than 1.5 m from the previous one. Drilling of wells near previously manufactured anchors is permitted only after at least 48 hours have passed since the completion of concreting of the latter.	
4	The load-bearing capacity of each anchor must be checked before it is put into operation together with the structure being fixed by conducting control or acceptance tests for the maximum test load.	
5	Before the commencement of work, security zones of existing underground and overhead communications, as well as underground structures, must be designated, indicating the security zone established in accordance with paragraph 3.22 of SNiP 3.02.01-87 " Earth structures, foundations and foundations"	
6	In case of detection of underground structures, communications or signs designating them that are not specified in the project, the work must be suspended, representatives of the customer and organizations operating the detected communications must be called to the work site, and measures must be taken to protect the detected underground devices from damage. The customer is allowed to remove existing communications from the work area with the written permission of the operating organizations.	

Table 6: Technology of Well Formation by Drilling in Unstable Soils (Subsequence)

1	Drilling should be performed using through-hole augers in accordance with the work execution project. As the auger is extracted, the borehole cavity is synchronously filled with a concrete mixture with a density greater than that of the soil, which ensures the stability of the borehole walls.
2	Drilling rig UBG-SG "BERKUT" or similar
3	Drilling is carried out from the working marks specified in the project.
4	To enable the drilling machines to turn and the anchor frames to be installed, the width of the soil berm must be at least 15.0 m.
5	During drilling, it is necessary to control the soil parameters at depth: establish the characteristics of the foundation soil based on the soil residues on the elements of the drilling tool, record this fact with a corresponding entry in the piling work log. Establish the conformity of the soil found at the bottom of the well and taken into account in the project at the level of the anchor root. If the depth of embedment of the drilling tool in this soil does not correspond, suspend the work and invite representatives of the design organization to make a decision (adjust the length, change the number of anchors, etc.). Work can be continued only after receiving permission from the author's supervision representative, which must be drawn up in the Author's Supervision Log

Below in Figures 1-5 are shown, respectively, an extract from the general plan of the construction site, an engineering-geological section of the construction site, a plan for the arrangement of the buried retaining structures of the construction pit, a diagram of the vertical reference of the buried retaining structures of the construction pit, a diagram of the vertical reference of the buried retaining structures of the construction pit with an indication of the placed process equipment.

Table 7: Technology of Cementation of a Borehole of a Ground Anchor in Unstable Soils

1	After drilling the well to the specified depth with a through-hole auger, fill the cavity of the auger with cement mortar B: C = 0.5:1, open the valve combined with the drilling column, and pump the mortar into the well through the cavity in the auger. After filling the free space under the bit, lift the auger with simultaneous continuous supply of cement mortar into the well. Synchronize the lifting speed with the speed of mortar supply into the well, for which it is necessary to control the movement of the cement mortar to prevent the formation of low pressure in the well under the auger
2	The cement mortar is filled to the wellhead
3	Prepare the cement mortar at the construction site immediately before pumping it into the well. The PRN-500 (PRN-300) pneumatic mortar pump is used to prepare and pump the mortar. Pumping pressure is 0.5-5.0 MPa.
4	The volume of cement slurry pumped into the well should be controlled, comparing it with the design volume and the volume of drilled soil, and the volume of slurry pumped into the well should exceed the volume of drilled soil.

Table 8: Program for Electric Discharge Treatment of a Well Filled with Cement Mortar

1	The power of accumulated energy is not less than 50.0 kJ
2	Cable length from GIT to the electrode system no more than 80.0 m, including the length of the anchor (high-voltage cable TYPE-2 - 50.0 m, high-voltage cable KVIM - 30.0 m)
3	Electrical discharge treatment is carried out along the length of the anchor root in series of at least 13 discharges at each level. The step of the levels is from 1.0 m. The calculated increase in the drill diameter (150.0 mm) is brought to 200.0 mm, for this purpose it is necessary to control the solution level in the well before the start of treatment of one level and after the completion of treatment. In this case, the solution level in the well during treatment of one level should decrease by at least 15.0 cm. Moreover, if during the last five electrical discharges the solution level decreases by more than 1.0 cm, continue treatment of the level until reaching "failure". A decrease in the solution level in the well during the last 5 discharges of no more than 10.0 mm is considered "failure". To establish the fact of "failure", monitor the change in the solution level in the well after each discharge or a series of 5 discharges
4	Ensure that the total volume of solution supplied to the well, including topping up, exceeds the geometric volume of the drilled well (the volume of soil extracted from the well)
5	Ensure that the total volume of solution supplied to the well, including topping up, exceeds the volume of the drilled well (the volume of soil extracted from the well)

Conclusion

In general, compliance with the sequence of the construction pit fencing using bored-tangent piles with a diameter of 630.0 mm and ERT ground anchors made it possible to construct a reliable retaining wall that ensures reliable operation of existing development facilities.

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