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Review Article

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Geotechnical Experience of Landslide Slope Reinforcement

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ABSTRACT
The problems of underground space development in the cramped conditions of existing industries are a complex geotechnical task and require a specific approach. At the same time, the presence of weak engineering and geological elements significantly complicates the implementation of geotechnical works. Increasing the bearing capacity of the foundation base is always under the close attention of geotechnicians, designers and builders. The use of bored piles arranged using non-standard physical processes in most cases successfully solves many complex and atypical geotechnical problems. The article is a review.

Keywords: Geotechnical Construction, Electrohydraulics, Monolithic Reinforced Concrete Grillage, Bored Injection Piles Ert, Constrained Geotechnical Conditions.

Construction of buildings and structures in areas not suitable for construction of objects without their preliminary pre-project preparation has recently acquired considerable relevance [1-13]. Often, builders neglect the concepts of stability of buildings and structures, reliability of engineering and geological conditions. At the same time, planning construction on unstable foundations, especially on leaning slopes, they make the most mistakes, which ultimately lead to a significant increase in the cost of the object. For example, when constructing objects on such construction sites, it is necessary to take into account both the reliability of the slope and the reliability of the embankment itself, poured on this slope, on which the object will be located. It is safe to say that builders build on such unstable sites in the same way as on flat territories. This is where all the troubles that arise after the end of construction and the beginning and during the operation of objects erected on such territories lie.

Below we consider the negative experience of capital construction and operation of the Lukoil gas station, erected on an unstable leaning slope. For practicing builders, this is an instructive example of "how not to build."

During the construction of a retaining wall and the construction of a sand semi-embankment with the placement of the operator's building and engineering infrastructure of the gas station on it, deformations and subsidence of the foundations of these objects occurred. In order to identify the causes of the deformations that occurred on the site of the reconstructed gas station, the survey organization carried out engineering and geological work at the site: The purpose of the survey was to obtain reliable engineering and geological data to determine the causes of the deformation of the leaning slope (semi-embankment) with the construction site of the reconstructed gas station (gas station), located on a landslide slope (leaning), and to develop technical recommendations for their prevention.

It should be especially noted that prismatic driven piles were used to reinforce the foundations of the control room and canopy buildings (see Figure 1-4). Moreover, the already driven piles are in under-compacted fill soils (they "hang" in the embankment, creating additional loads and worsening the work of the foundation). They do not participate in the reinforcement

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of the foundation at all, one might even say they hinder it. The designers made a gross mistake, which consists in the fact that in the working drawings of the project they did not seal the lower ends of the piles in a reliable engineering-geological element. As a result, an unstabilized process of deformation of the gas station objects occurs:

1. Collection and analysis of materials from previously completed engineering surveys; 2. Identification and mapping of the location of areas of hazardous engineering-geological processes in the survey area; 3. Study of the geological and lithological structure of the survey area; 4. Study of the hydrogeological conditions of the survey area; 5. Study of the physical and mechanical properties of soils using laboratory and field methods; 6. Determination of the presence of specific soils and characteristics; 7. Assessment of slope stability to substantiate design solutions for engineering protection of the area; 8. Calculation of design landslide pressures for the design of landslide prevention measures (MPM).

Based on the conducted surveys, the engineering-geological structure of the reconstruction site up to the depth investigated by drilling new and archive wells (40.0 m) is represented by bedrock of the Severodvinsk and Vyatkian stages of the Upper Permian division (**P3**$_{s+v}$) **within** the plateau - covered from the surface by fill soils (**tQh**), on the landslide slope section - by Quaternary $_{\text{landslide deposits}}$ **dpQ (prQp) ; dp Q (P3**$_{s+v}$**)** and fragments of the embankment (**tQ**$_h$), and in the floodplain - alluvial deposits of the Trusikha River (**aQ**$_{h-p}$) - on the site of the old channel planned man-made embankment (**tQ**$_h$). According to laboratory tests, taking into account the geological structure and lithological features of the soils and in accordance with GOSTs 25100-2016 "Soils. Classification" and 20522-2012 "Soils. Methods of statistical processing of test results" 15 engineering-geological elements were identified on the studied sites (**IGE**). According to the results of the research, two IGEs were identified - bulk soils. These are **IGE-1** and **IGE-2**. They are represented by uncompacted layers of uncompacted fine sands from loose to medium density, as well as loams with clay interlayers.

At the customer's request, we developed a project for landslide retaining geotechnical measures using ERT bored piles and ERT ground anchors manufactured using electric discharge technology. ERT ground anchors with a length of l = 20.0 meters at an angle of 40.0 degrees to the vertical at an absolute elevation of +94.60 m were developed to ensure the stability of the existing retaining wall constructed from bored piles to reinforce the slope. Due to the absence of recessed spacer (retaining) structures in the operated wall, it received horizontal deformations of up to 20.0-50.0 cm. The device of ERT ground anchors passed through the existing monolithic reinforced concrete strapping belt and fixed to it using rolled sections - channels at this elevation of +94.60 m made it possible to stabilize the horizontal deformations (see Figure 1 and 2). Preliminary results of high-precision engineering and geodetic observations indicate this.

In addition, a retaining, protective, anti-landslide braced retaining wall was developed at the absolute elevation of 103.500 m from two rows of bored-injection piles ERT with the lower end elevation of 86.50 m and ERT soil anchors 20.0 m long at an angle of 40.0 degrees (see Figure 1). The bored-injection piles ERT are connected at their tops by an angular monolithic reinforced concrete retaining wall with buttresses, through which the ERT soil anchors are passed. These anti-landslide reinforced concrete structures serve to ensure the planned geometry of the leaning slope. Thus , the implementation of emergency geotechnical measures made it possible to stabilize and reduce the leaning slope deformations to minimum values. The results of further geotechnical monitoring of deformations indicate the correctness of the adopted technical solution for stabilizing deformations of the unstable slope.

At the same time, the objects built on the surface of the leaning slope, due to insufficient fixing of the base (the driven piles are not embedded with their lower ends in a reliable layer) continue to deform. At the same time, they continue to deform with a list towards the slope. Analyzing the diagrams shown in Figure 2 and 3, it can be seen that the existing piles are within the thickness of the fill soils, which are in an under-compacted state. That is, the bearing capacity of these piles on the soil turned out to be zero. Thus, taking this into account, the existing piles with negative friction additionally load the objects in question.

In order to stabilize the deformation of the above-mentioned objects, ERT bored-injection piles were used with the lower end embedded in an incompressible reliable foundation (pos. 2 in Figure 1-4). The ERT piles for the canopy object are arranged through a monolithic reinforced concrete grillage between the existing piles. Due to the particular constraints in performing work to strengthen the base of the operator's room foundations, a decision was made to install a cantilever monolithic reinforced concrete beam brought under the base of the existing monolithic reinforced concrete grillage (see Figure 3-5). In this case, the beams simultaneously served as grillages over the ERT bored-injection piles. These structures were brought under all the existing monolithic reinforced concrete grillages, due to which the settlements of the existing foundations of the operator's room building were stabilized.

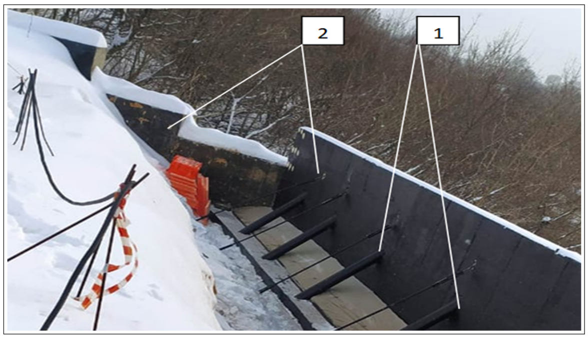

Figure 1: Photograph of the anchor fastening of the deformed slope on the landslide slope at an absolute elevation of 94.60 m: 1 - ERT ground anchor; 2 - monolithic monolithic reinforced concrete corner retaining walls

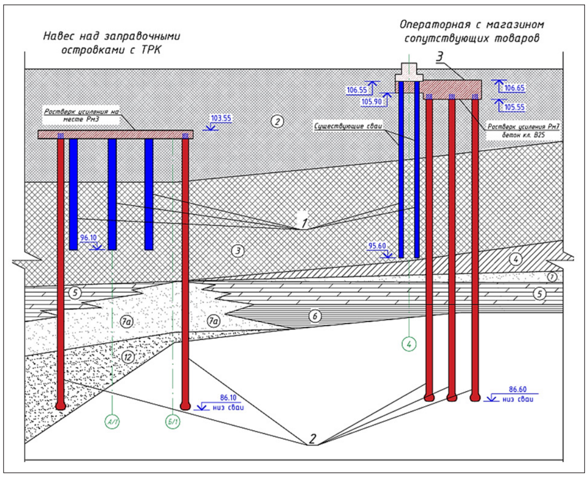

Figure 2: Engineering-geological section: 1 - existing driven piles; 2 - bored-injection piles ERT ; 3 - supplied monolithic reinforced concrete cantilever beams for existing monolithic reinforced concrete grillages

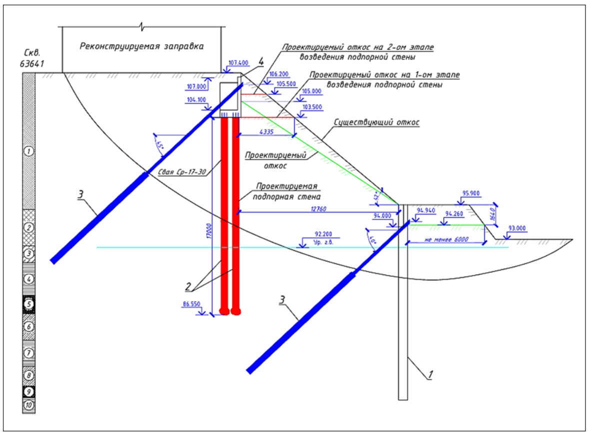

Figure 3: Cross-section of a leaning slope with anti-landslide recessed reinforced concrete structures.

1 - existing retaining wall made of bored piles with a diameter of 500.0 mm; 2 - bored piles ERT for reinforcing the base in two rows; 3 - ground anchors ERT for reinforcing the slope; 4 - monolithic angle reinforced concrete retaining wall.

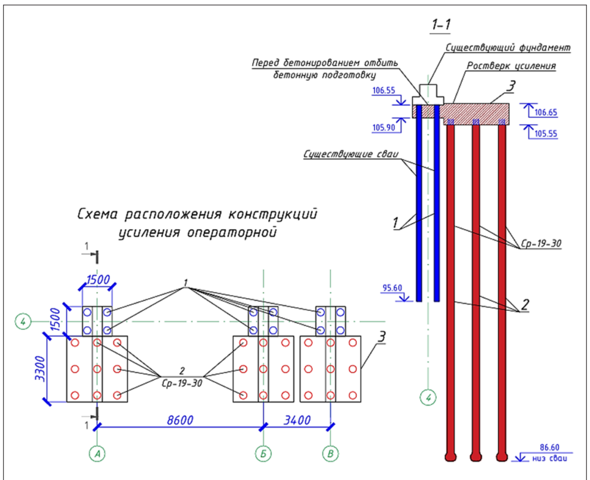

Figure 4: Scheme of strengthening the base of the control room foundations

1 - existing driven piles; 2 - bored injection piles ERT; 3 - supplied monolithic reinforced concrete cantilever beams under the existing reinforced concrete grillages.

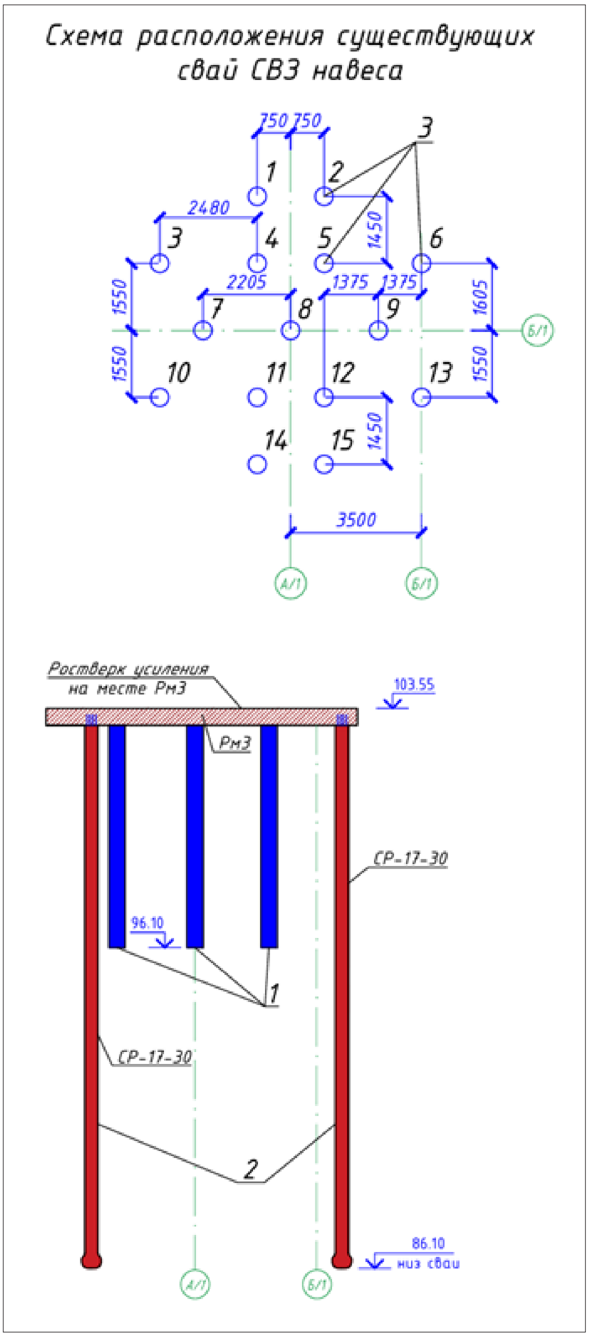

Figure 5: Scheme of reinforcement of the foundation base of the canopy: 1 - existing driven piles; 2 - bored piles ERT

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