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LANDSLIDE REMEDIATION ON LOCATION OF TRANSMISSION LINE POLE SM 134 ON DV 110 kV TS TUZLA C. – TS DUBRAVE

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ABSTRACT

The aim of the paper is to show the landslide that damaged the transmission line pole, and its remediation. The landslide is located in Tuzla, and the microlocation of the facility is located in the area of the Dolina and the settlement of Vrapče. The remediation was made on the basis of a study on the characteristics of the terrain and the design of the basic structure of the pillar.

Remediation measures include: construction of protective canals, drainage of water from individual branched canals on the surface of the sliding body, closing cracks and accepting water from them, and planning the entire surface of the landslide. Based on the analysis of the problem at the location in question, the most optimal and safest solution for the remediation of the mentioned slope should be provided.

Key words: *landslide, geological profile, remediation, pile, anchor*

INTRODUCTION

Slope stability assessment is an important problem of applied soil mechanics. Experience shows that slope instability is mostly manifested as sliding of the ground mass, or sliding body, on a flat or curved sliding surface [1]. The paper presents the analysis and remediation of landslides on the southwestern slope of the city of Tuzla, and the microlocation of the structure is located in the area of the Valley between elevation 389 and the settlement Vrapča [2].

After the torrential floods in the city of Tuzla in 2014, due to which the transmission line pole was damaged after the landslide, there is a need for a permanent solution to this problem. Therefore, at the request of JP Elektroprijenos BiH, the Project for the basic construction of the SM 134 pillar was prepared. In this respect, remedial measures should be implemented, which will be mentioned in further analysis [2].

During the execution of works, the contractor is obliged to comply with the Law on Occupational Safety and Health and other positive technical regulations that treat this area, and to resolve all ambiguities in time with the designer [2].

The project was made on the basis of the Study on engineering geological and geomechanical characteristics of the terrain with a geotechnical project report [3].

The aim of the study was to address the situation on the ground, which, among other things, concern the remediation measures themselves, with optimal conditions from the technological and economic population [3].

DESCRIPTION OF THE CURRENT SITUATION

The location of the pole site SM 134 is located on the southwestern slope of the city of Tuzla, and the microlocation of the structure is located in the area of the Valley between elevation 389 and the settlement Vrapča. Access to the location is on the right side of the road Tuzla - Slavinovići, across the local road through the village Vrapče, Figure 1.

The microlocation of the pole site was determined by coordinates according to the Gauss-Krieger network: $x = 6554699,74$ and $y = 4931170,85$. Morphological conditions at the site are assessed as relatively favorable. In nature, it is a slightly steep slope, almost flat plateau, formed by erosion and denudation processes in the phase of the sedimentation cycle of the middle and lower Miocene. A visit to the site revealed the problem of landslides on the slope around and above the place where the pole should be based [2].



Figure 1 Ground situation after the landslide

RESEARCH METHODOLOGY

The following activities were performed in achieving the basic goals and tasks of field geological and geotechnical research works [2]:

- Exploratory drilling
- Sampling for laboratory tests
- Photographing and geological mapping of exploration wells and excavations
- Standard dynamic penetration test (SPT experiments)
- Geological and engineering-geological research
- Office data processing and preparation of studies and projects

1 exploratory well, 15.0 m long, was drilled.

During the construction of exploratory wells, certain activities, “in situ” tests, and observations were performed, as follows [2]:

- Sampling of soil and rock materials. Disturbed samples were taken for standard geomechanical analysis. Samples were taken from each exploration well, when changing lithological members at depths where it is necessary to determine the quality of the material. After sampling the materials, they are properly packed and shipped to the laboratory.
- The standard Penetration Test (SPT) was performed on every 3, 0 m of the well.
- Monitoring of GWL (groundwater levels);
- Placing the drilled core in appropriate crates, marking and mapping the core from the exploration wells and taking photographs before the start of the mapping and after its completion, and taking undisturbed samples;

4 soil and rock samples were selected for laboratory tests at the thematic station.

All tests on gravel, stone fragments and clay were performed according to BAS CEN ISO/TS 17892 standards [4,5,6]:

- | | |
|-----------------------------|--|
| • natural humidity | BAS CEN ISO/TS 17892-1: 2016 |
| • bulk density | BAS CEN ISO/TS 17892-2: 2018 |
| • specific weight | BAS CEN ISO/TS 17892-3: 2017 |
| • granulometric composition | BAS CEN ISO/TS 17892-4: 2002 |
| • consistency limits | BAS CEN ISO/TS 17892-12: 2009 - 12/Cor1:2009 |
| • shear strength | BAS CEN ISO/TS 17892-10: 2009 - 10/Cor1:2009 |
| • compressibility | BAS CEN ISO/TS 17892-5: 2018 |

Classification characteristics (moisture content, bulk density and granulometric composition) were examined on all gravel samples, while shear strength and compressibility as well as classification characteristics were examined on clays [3].

RESEARCH RESULTS

The following field characteristics were defined by the conducted field research and laboratory testing:

Engineering geological characteristics of the terrain

In the engineering geological sense, the following soil categories can be distinguished at the subject location:

- surface cover,
- weakened substrate or “decomposition crust”,
- geological substrate.

The surface cover is represented in the surface part of the terrain. It is built of colluvium, multicolored clays and sandy clays with a layer of gravel. Clays have plastic consistency, and very variable and uneven physical and mechanical properties, which mainly depends on natural humidity. In the air dry state they have relatively favorable properties, whereas in the state of natural humidity they have plastic consistency, subject to the processes of swelling and increased subsidence.

For this reason, construction in these areas requires special care due to the possibility of uneven subsidence.

Weakened substrate or decomposition crust is represented by gray to gray-green hard clays with more favorable physical and mechanical properties compared to surface cover clays.

The geological substrate is gray siltstone marls. This horizon has a pronounced layered to laminar texture and pelitic to siltstone structure, and high values of penetration resistance. In the presence of water, they change their water-physical and physical-mechanical properties relatively quickly.

Therefore, in the conditions of construction of the planned contents, the excavations should be avoided to be open for a long time and exposed to external influences. This means that after reaching the projected depth of excavation, the installation of materials should be started immediately, and the rest of the excavation should be buried in order to prevent the destructive action of external agents. Otherwise, marls are a good basis for structure foundation. According to the basic geological map, in Tuzla, their thickness is between 20 and 70 m [2].

Detailed engineering-geological mapping of the core of the exploration well performed on the microlocation of the line pole showed that the soil in the engineering-geological sense builds eleven (11) horizons, as follows [2]:

- HORIZONT (1) consists of colluvial material 1, 30 m thick;
- HORIZONT (2) is a gray-dark clay 0, 50 m thick;
- HORIZONT (3) consists of light brown sandy silty clay 0, 90 m thick;
- HORIZONT (4) is a gray-brown slightly sandy clay, 0, 70 m thick;
- HORIZONT (5) consists of gray-green plastic clay with a layer of gravel 0, 20 m (mark 6), total thickness 1, 00 m;
- HORIZONT (7) is a light brown clay with iron inlays, 1, 90 m thick;
- HORIZONT (8) consists of gray-green plastic clay, 0, 70 m thick;
- HORIZONT (9) is a gray hard clay, 0, 90 m thick;
- HORIZONT (10) is gray to gray-green clay, hard, 1, 05 m thick;
- HORIZONT (11) are gray siltstone marls whose thickness to the extreme depth of the well is 6, 05 m. [2]

Geotechnical terrain model

The geotechnical model of the terrain at the subject location consists of [3]:

- Geotechnical environment GS 1, which is represented by colluvial deposits, alluvial-delluvial cover and weakened geological substrate. It is built of sandy clays with fine plate inclusions of crumbs, sandy clays with a layer of gravel and clays, and sandy clays. The thickness of the cover is up to 9, 00 m.
- Geotechnical environment GS 2 is represented by marls.

To determine the relevant parameters of the GS 1 cover material in its natural state, a feedback analysis was performed in the Plaxis software package [7,8].

The calculation was performed on the most critical cross-sectional profile [7]. It is assumed that the landslide is in a state of boundary equilibrium, i.e., that the safety factor is $F_s = 1,000$. Figure 2 shows the most critical sliding surface in the natural state, obtained by calculation based on field and laboratory exploration, engineering geological determination and classification of exploration well core, as well as the results of feedback analysis. The following calculated soil parameters for selected geotechnical environments were determined: [3]

- For geotechnical environment cover materials GS 1: deformability modulus $E_s = 5$ MPa; bulk density $\gamma = 17,5$ kN/m³; internal friction angle $\varphi = 15^\circ$ and cohesion = 5, 5 kPa.
- For materials of geotechnical environment GS 2: modulus of deformability of rock mass $E_s = 250$ MPa; bulk density $\gamma = 20$ kN/m³; internal friction angle $\varphi = 23,5^\circ$; cohesion = 20 kPa.

It should be noted that the values obtained by laboratory testing are somewhat lower, but those obtained by back-analysis in the Plaxis software package were adopted. The adopted values are the same as those in the literature [3].

The numerical model is built in the Plaxis software package and consists of soil elements, static external load conditions and boundary conditions. After creating a numerical model, the initial calculation of the current state is performed. Given the obtained safety factor, it is concluded that the designed structure is stable [9].

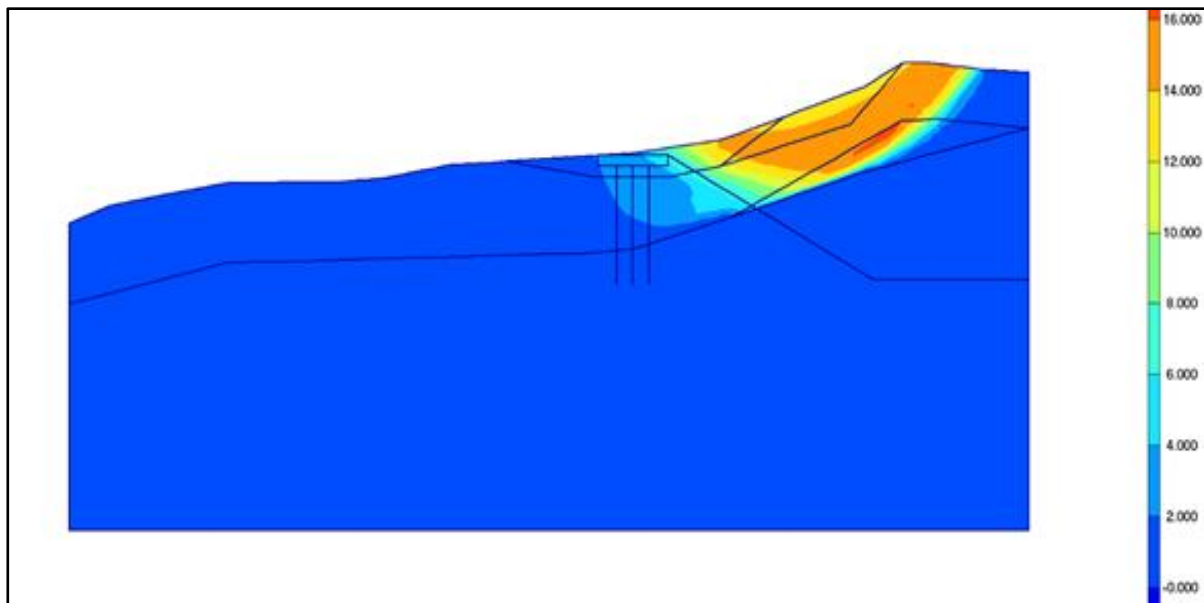


Figure 2 Calculation of slope stability for natural condition $F_s = 1,000$

Proposal of preliminary remedial measures

After considering several possible solutions, from a technological and economic point of view, it seems optimal that the project solution consists of the following: [3]

- drainage of the slope with a drainage channel placed in front of and above the place of foundation of the pillar and controlled drainage of the collected water through pipes and channels down the slope,
- construction of 9 drilled piles $\varnothing 600$ mm and 11 m in length, provided that they must enter the substrate at least 3,00 m,
- Installation of stone material under the ground plane, approx. 1,00 m thick,
- Construction of a ground plane with measures 9.00 x 9.00 m and 1.00 m thick, which will connect and stiffen the piles,
- Installation of pre-stressed anchors, 20 m long, in the ground plane. The anchors must enter the substrate materials at least 12 m. The anchors are pre-stressed to a force of 250 kN
- Installation of stone material, as a supporting structure that will stabilize the slope above the foundation of the pillar
- Cleaning the existing culverts and gutters.

Calculation of the stability of the remediated slope

In the second phase of the calculation, the analysis of the remediated slope was performed and the safety coefficient $F_s=1,320$ was obtained. Figure 3 shows the most critical sliding surface of the remediated slope [3].

The calculation was carried out in accordance with EuroCode 7, design approach PP1. The combination of partial safety factors is given in Table 1 [10].

Table 1 EC7 – Partial safety factors

Project approach	Impacts and effects of impact		Soil resistance
	Construction		
GEO – PP1 comb. 1	$\gamma_G = 1,35; \gamma_Q = 1,50$		$\gamma_\phi = \gamma_c = 1,00; \gamma_{cu} = 1,0$
GEO – PP1 comb. 2	$\gamma_G = 1,00; \gamma_Q = 1,30$		$\gamma_\phi = \gamma_c = 1,25; \gamma_{cu} = 1,4$

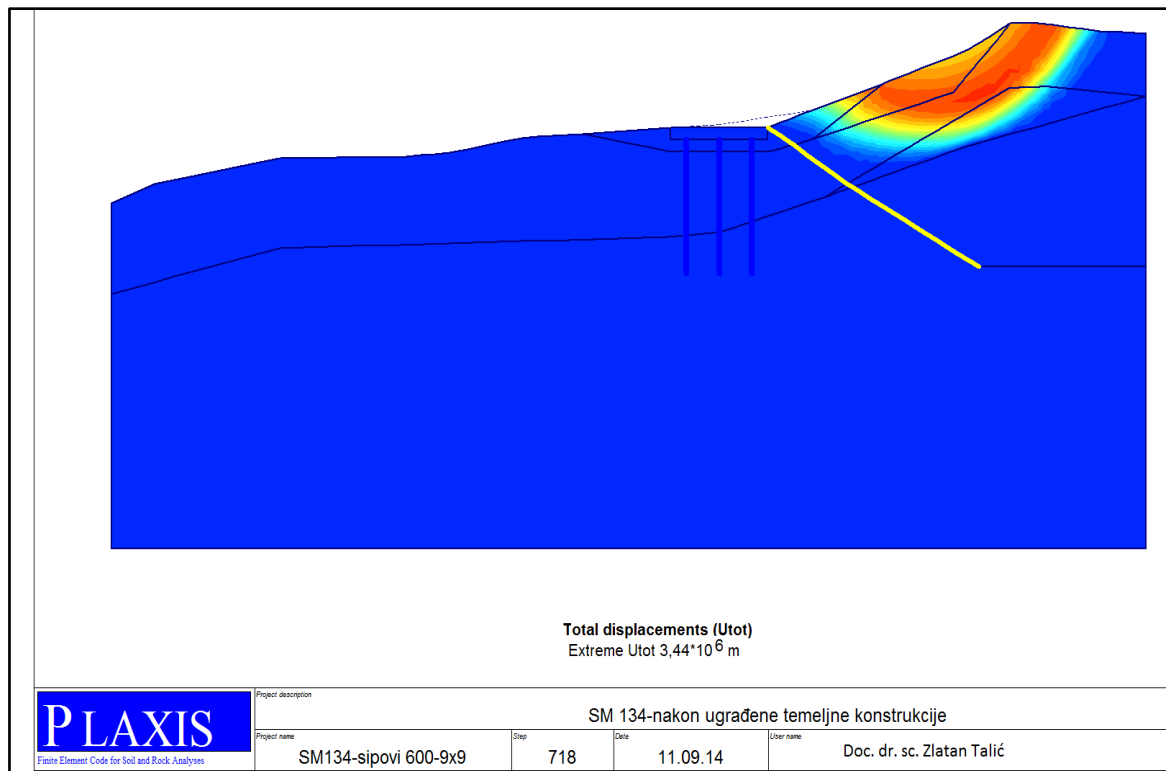


Figure 3 Calculation of slope stability for repaired condition $F_s = 1,320$ [3]

In addition to this calculation, a stability check was performed in the Geo 5 program for the same geotechnical terrain model and design solution. The calculation model in 3D is shown in Figure 4.

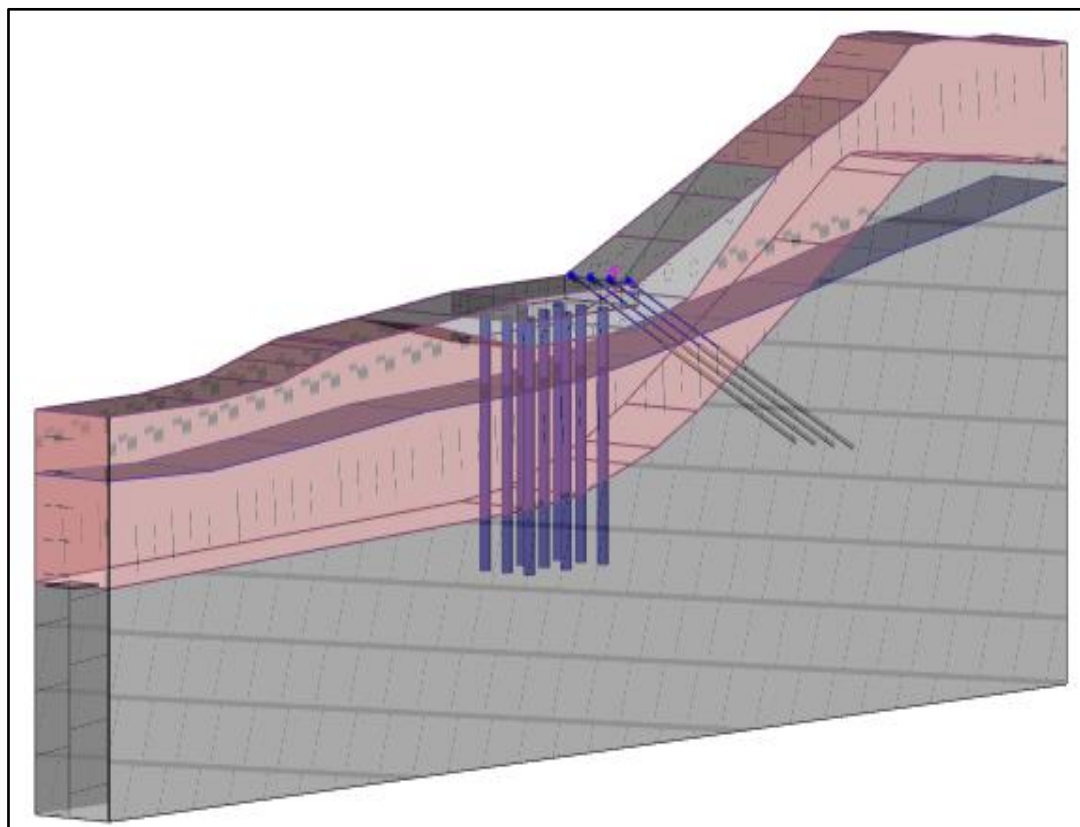
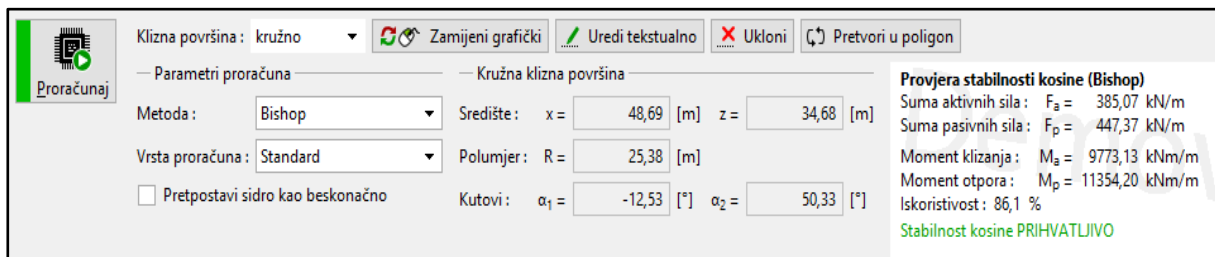


Figure 4 Calculation of slope stability for repaired condition in software Geo5

Results of calculation in Geo5 program.



The results in Geo5 program show that the slope is stable.

After the analysis of geotechnical exploration works, it was concluded that it is necessary to remediate the landslide by making the following stabilization elements:

- Drainage of the slope with a drainage channel placed in front of and above the place of foundation of the pillar and controlled drainage of the collected water through pipes and channels down the slope,
- Construction of 9 drilled piles of $\varnothing 600$ mm and 11 m long, provided that they must enter the substrate at least 3,00 m,
- Installation of stone material under the ground plane, approx. 1,00 m thick,
- Construction of a ground plane with measures 9.00 x 9.00 m and 1.00 m thick, which will connect and stiffen the piles,
- Installation of pre-stressed anchors, 20 m long, in the ground plane. The anchors must enter the substrate materials at least 12 m. The anchors are pre-stressed to a force of 250 kN
- Installation of stone material, as a supporting structure that will stabilize the slope above the foundation of the pillar
- Cleaning the existing culverts and gutters.

This proposed solution is in line with the literature recommendations for landslide remediation [11].

The solutions are shown in Figure 5 for normal transverse remediation profile.

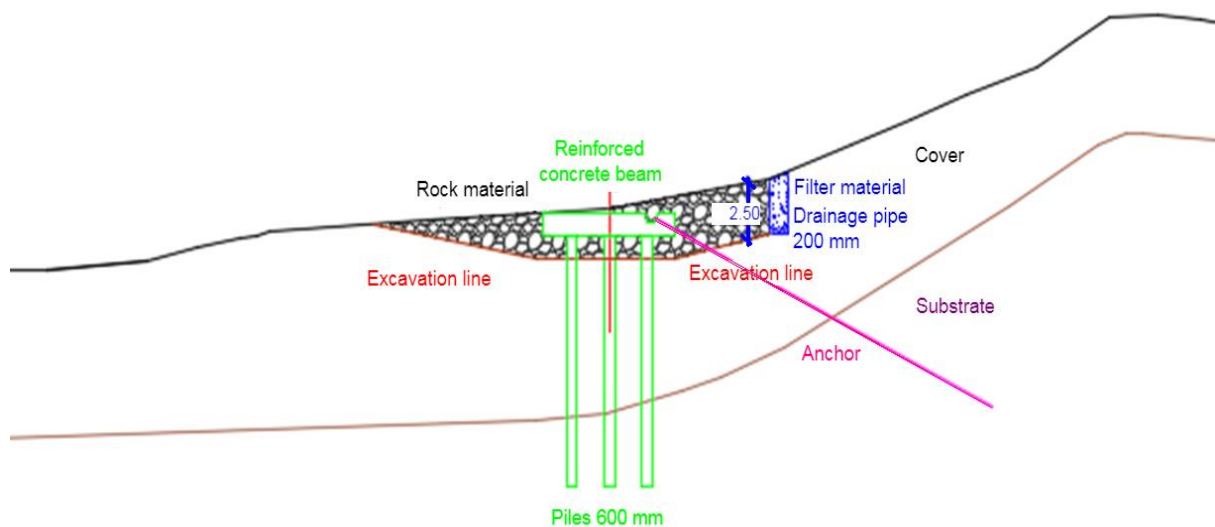


Figure 5 Normal transverse remediation profile

Based on the analysis of the problem at the location in question, the most optimal and safest solution for the remediation of the mentioned slope was given [3]. Figure 6 shows a picture of the terrain after remediation.



Figure 6 Image of the terrain after remediation

DISCUSSION

Excavation and stabilization works will begin after the completion of preparatory works, especially geodetic stakes. The terrain is cleaned, after which excavation works can start, drainage can be laid, and a supporting structure will be built. It is obligatory to perform all works in a hydrologically favorable period [12].

The works must be performed in an order that allows for the continuity of the excavation and the optimal use of machinery.

Excavations to the required depth should be performed mechanically, with gradual lowering and in segments. Deviations of the excavation geometry from the designed geometry are not allowed.

The excavation of drainage trenches is carried out in segments up to 4.0 m. After that, the next segment is laid [3]. At the end of one segment, concrete flume is performed, drainage pipes are installed, and it is filled with filter material. After that, the next segment is built [3].

During excavation works, the following should be controlled:

- the excavations are carried out according to the designs and elevations of the project,
- to ensure proper drainage during excavation works until the end of the works.

The depth of the excavation is geodetically controlled.

Due to the danger of buckling, the stability of the piles is calculated by computer, both for the free lengths of the piles off the ground and for the lengths of the piles through the soil layers in a liquid consistency.

Stone material is being installed, as a supporting structure that will stabilize the slope above the foundation of the pillar. These works are performed in layers with appropriate compaction. It is necessary to compact the stone material to a compressibility modulus of 60 MPa [13,14].

CONCLUSION

The paper presents landslide remediation performed on the basis of research and testing of samples, and lists those measures that will help to remediate the landslide or partially mitigate its further effects. These measures include: construction of protective canals, drainage of water from individual branched canals on the surface of the sliding body, closing cracks and receiving water from them, and planning the entire surface of the landslide [15].

After the analysis of geotechnical exploration works, it was concluded that it is necessary to remediate the landslide by making the following stabilization elements:

1. Drainage of the slope by a drainage channel placed in front of and above the place of the pillar foundation and controlled drainage of the collected water through pipes and channels down the slope,
2. Execution of 9 drilled piles with $\Phi 600$ mm and 11 m length, provided that they must enter the substrate at least 3,00 m,
3. Installation of stone material under the ground plane, approximately 1,00 m thick,
4. Production of a ground plane measuring 9.00 x 9.00 m and 1.00 m thick, which will connect and stiffen the piles,
5. Installation of pre-stressed anchors, 20 m long, in the ground plane. The anchors must enter the substrate materials at least 12 m. The anchors are pre-stressed to a force of 250 kN,
6. Installation of stone material, as a supporting structure that will stabilize the slope above the pillar foundation.

These solutions are shown in Figure 4, i.e., normal cross-sectional remediation profile.

Based on the analysis of the problem at the location in question, the most optimal and safest solution for the remediation of the mentioned slope was provided [3].

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