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LAND SLIDE STABILIZATION FOR A WORKING PLATFORM WHICH OCCURRED DURING EXCAVATION IN CLUJ-NAPOCA

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Abstract: *The present study contains the technical data and design method, with details, regarding the stabilization of a landslide using drilled piles on a site from Faget area in Cluj-Napoca where a family home is to be constructed. A landslide occurred during the excavations on a slope through which drainage was oriented from the area, without former measures to avoid such phenomena. In order to regain the slope's stability and resuming the project, it was proposed a consolidation solution to prevent any further landslides and a safe way for the building process. In this paper it is presented the slope analysis method and design method for the landslide stabilization with some aspects regarding the final technical solution.*

Key words: *landslide stabilization, drainage, slope, piles.*

1. Introduction

A home with ground floor and one floor up will be constructed on the site from Cluj-Napoca Faget, 34C D.D. Rosca Street. After the foundation excavation for the building was made, a landslide took place which affected the respective place and the neighboring parcels from upstream.

In order to stabilize the landslide was proposed a pile wall upstream of the excavation to support the earth and a building located nearby and to prevent the extension of the landslide. A new geotechnical survey was necessary for the design of the stabilization solution.

The landslide stabilization design method for combines slope stability analysis with the piled wall design using the subgrade of reaction modulus method.

2. Site Description

The site in question is located in Cluj-Napoca in Faget area in downstream slope of the road Cluj-Napoca - Ciurila, behind the former Faget camping. The building to be made is a residential home (Figure 1). From a geomorphological point of view the site is part of the Transylvanian Depression and the central-eastern side of the Someșan Plateau. The landscape is predominantly hilly. The whole slope is

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covered with new buildings. The site is located on the middle of the slope. The inclination of the slope is approx. 10°. At the upstream limit of the site there is a steeper slope, with an approximated height of 1.50 m, formed artificially by earth depositing. The general inclination of the slope is about 12°. It is important to notice that despite the inclination of the slope from south-east to north-west, the surrounding terrains have an inclination towards the site in question, which makes the meteoric water to line up on this terrain not only from upstream but also from the side lanes [5]. Based on previous observations of the terrain in upstream of the new construction it has been noted that since 3 years ago the terrain has always been saturated with water resulted from the excavations and drainages from the terrains upstream. In the upper right corner upstream there is a home with two pipes for draining water. There is also an evacuation pipe from this place but the home shows signs of damage so the water falls onto the terrain. Furthermore, the vegetation here corresponds to a swampy one and the terrain is always soaked. From further observations it was noticed that 2-3 years ago the drainages from upstream were continued on the investigated terrain and the water was eliminated. Besides these facts from the geotechnical survey were not intercepted any water levels. On the left side a drainage tube has truly been intercepted, draining the water downstream from the terrain.

The foundation system is a raft beneath the building with a thickness of 35cm. In order to build the raft a general excavation was made, with an average height of 3 meters and peaks about 4.5 meters with slopes about 70 to 80 degrees.

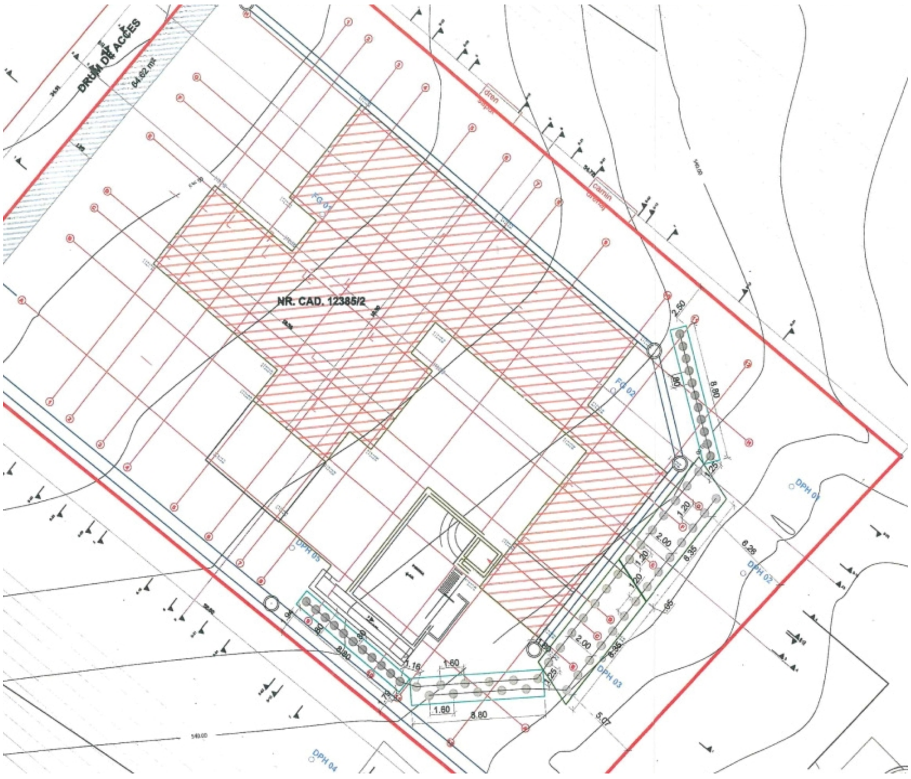


Fig. 1. *Building and consolidation plan*

In short time after the excavation began the earth started to move from the right upstream of the excavation. The earth movement was caused by the big excavation height, but the area of the landslide was much bigger than the slide caused by excavating using big slopes. Upstream from the new building location was a small swamp that was probably the remains of a former landslide in the neighbor area. In the nearby region of the excavation the wooden floor from the ground level of a coop was showing signs of recent movements, the fence between neighboring properties were showing signs of movements and some cracks started to appear in the soil. The landslide area was very close to some buildings in the area, but none of these were showing signs of movement or cracks.

The length of the landslide affected area is about 20m, from which 10m on the upstream terrain. The width of the affected area is about 35 m from which 8m are on the right side neighbouring terrain. After the landslide was produced, the constructor filled the excavation with earth. After this fill the landslide did not evolve significantly.

According to the geotechnical survey data, two types of soil layers have been intercepted: from the terrain level up to about 3.5m is a silty brown-yellow consistent clay, from 3.5m depth up to the toe of the drilling a silty brown-grey firm clay was found. After the landslide occurred five more dynamic penetrations were made. The penetration diagrams were indicating a weak soil layer for about 3m in depth, which led to the conclusion that this could be the possible depth of the landslide. The average layer depths and soil characteristics are shown in Table 1.

3. Slope Stability Analysis

The usual pattern followed to consolidate a slope with potential of a landslide is to analyze the slope stability in order to find the sliding surface with the biggest potential [4]. This potential is usually expressed by the safety factor (Fs) which represents the ratio between the resistive forces/ rotating moments and destabilizing forces/rotating moments, depending on the method of analysis. If this safety factor is showing values under 1.0 it's a clear sign of slope instability but in current practice this value is limited to a minimum of 1.4÷1.5 in order to compensate the lack of knowledge or some destabilizing matters

that somehow could be overlooked or need further complex investigations which are time and cost ineffective.

For a slope that could be affected by a landslide it is necessary to know mainly the shear strength of the soil, expressed through shear strength parameters: the internal friction angle Φ and cohesion c.

The average layer depths and soil characteristics from geotechnical survey Table 1

No.	Layer description	Depth from terrain level [m]	Soil characteristics		
			γ [kN/m^3]	c' [kN/m^2]	ϕ' [°]
1	silty clay, consistent, brown-yellow	0.00÷3.50m	19.7	17	9
2	silty clay, soft consistent , brown-yellow	3.50m÷4.00m	17.9	15	7
3	silty clay, firm, brown-grey	4.00m÷8.00m	20.7	35	15

If the stability analysis is made for a slope on which the landslide did not take place, the shear strength parameter values used are those determined by the attempts, namely medium or peak values. In the case of a landslide that already took place the slope analysis is made by means of so called residual values for the Φ and c parameters which are of course lower than the peak or medium ones. Generally the values could be introduced as $\Phi r = (1/2 \div 1)\Phi$ and $cr = (0 \div 1/2)c$. Since the landslide occurred on the site, the slope stability analysis was made using the residual values as shown in Table 2.

The slope stability analysis in this case was made for proposed known surfaces that could occur during landslide by means of blocks method. This method consists in dividing the sliding terrain in vertical blocks and to set for each block of the active force and the resisting force. The ratio between the sum of the resisting forces and the sum of the active forces of all the blocks is the coefficient of safety at sliding, and the pushing force of the sliding terrain is the difference between these forces.

The results of slope stability for different proposed sliding surfaces are presented in Table 3.

As shown in Table 3 the minimum safety factor was obtained in case 5 – slip surface (F_s=0.68) and it is lower than 1.0 which shows the clear sign of landslide.

4. Consolidation Solution

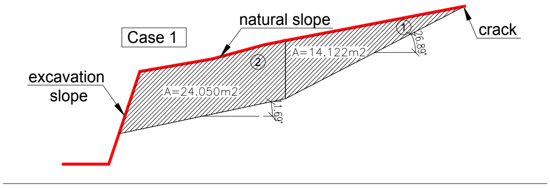
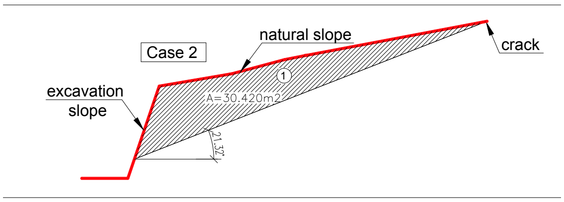
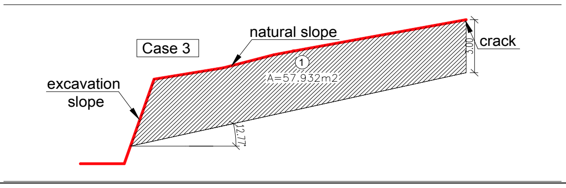
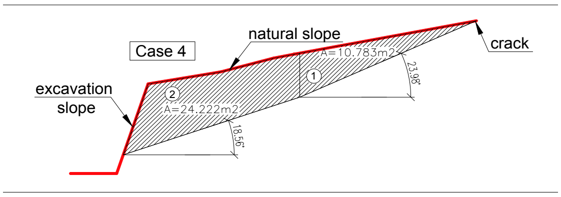
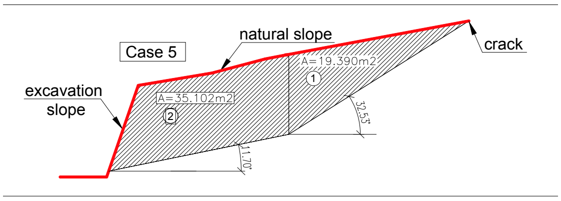
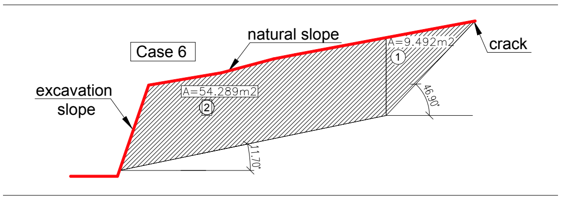
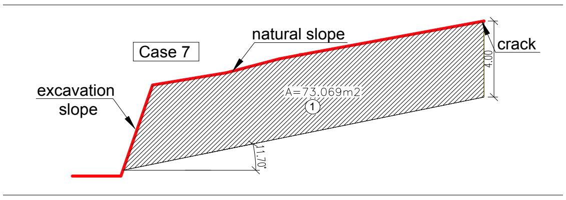
The method used for slope stability analysis provides the value for safety factor and the active force that the retaining structure should support [1, 3, 6]. As a retaining structure was proposed, a pile wall with piles anchored in the rigid soil layer at the toe and connected at the pile head with a raft/beam. From the stability analysis the earth active force acting on the piles is about 315 kN/m, and it was obtained from the lowest safety factor. The piles are 600mm in diameter and 12m long with spacing between them of 1.2m÷2.0m to allow water drainage (Figure 2).

The design method for the pile wall is using the subgrade of reaction modulus. By using this method the forward results are presented: horizontal displacements of the pile wall, horizontal pressure in the foundation soil, shearing force and bending moments along the pile [1, 3,7].

The average layer depths and residual soil characteristics Table 2

No.	Layer description	Depth from terrain level [m]	Soil characteristics		
			γ [kN/m^3]	c_r' [kN/m^2]	ϕ_r' [°]
1	silty clay, consistent, brown-yellow	0.00÷3.50m	19.7	5	7
2	silty clay, soft consistent , brown-yellow	3.50m÷4.00 m	17.9	5	7
3	silty clay, firm, brown-grey	4.00m÷8.00 m	20.7	35	15

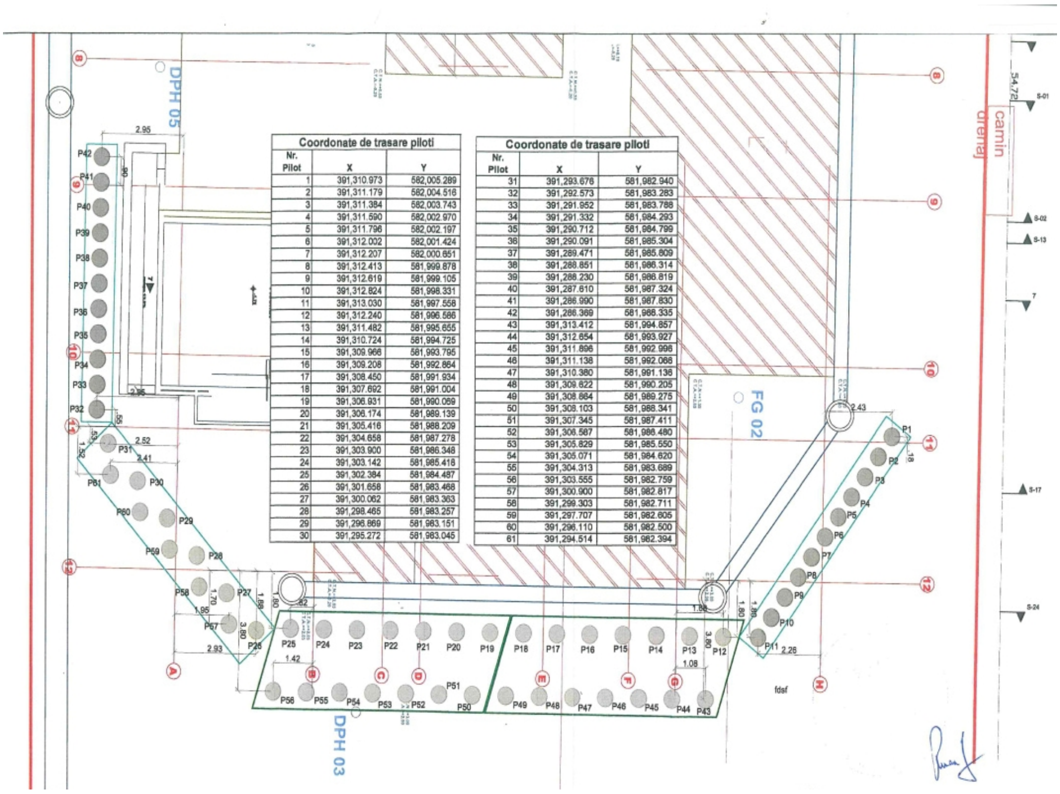
Safety factor for proposed slip surface Table 3

No.	Safety Factor (F_s)	Slip Surface
1	0.98	
2	0.81	
3	0.95	
4	0.77	
5	0.68	
6	0.73	
7	0.95	

By using these outputs the reinforced concrete elements were designed to sustain the earth active force.

The consolidation solution for the working platform also included a drainage system (Figure 3) that should collect the rain water from neighbor areas and possible water flow from underground [2].

The consolidation solution also includes a change of the foundation system for the new building to prevent any further damages. The new foundation system consists of micropiles or piles anchored in the rigid soil layer.



Coordonate de trasare piloti

Nr. Pilot	X	Y
1	391,310.973	582,005.289
2	391,311.179	582,004.516
3	391,311.384	582,003.743
4	391,311.590	582,002.970
5	391,311.796	582,002.197
6	391,312.002	582,001.424
7	391,312.207	582,000.651
8	391,312.413	581,999.878
9	391,312.619	581,999.105
10	391,312.824	581,998.331
11	391,313.030	581,997.558
12	391,312.240	581,996.586
13	391,311.482	581,995.655
14	391,310.724	581,994.725
15	391,309.966	581,993.795
16	391,309.208	581,992.864
17	391,308.450	581,991.934
18	391,307.692	581,991.004
19	391,306.931	581,990.069
20	391,306.174	581,989.139
21	391,305.416	581,988.209
22	391,304.658	581,987.278
23	391,303.900	581,986.348
24	391,303.142	581,985.418
25	391,302.384	581,984.487
26	391,301.658	581,983.468
27	391,300.062	581,983.363
28	391,298.465	581,983.257
29	391,296.869	581,983.151
30	391,295.272	581,983.045

Coordonate de trasare piloti

Nr. Pilot	X	Y
31	391,293.676	581,982.940
32	391,292.573	581,983.283
33	391,291.952	581,983.788
34	391,291.332	581,984.293
35	391,290.712	581,984.799
36	391,290.091	581,985.304
37	391,289.471	581,985.809
38	391,288.851	581,986.314
39	391,288.230	581,986.819
40	391,287.610	581,987.324
41	391,286.990	581,987.830
42	391,286.369	581,988.335
43	391,313.412	581,994.857
44	391,312.654	581,993.927
45	391,311.896	581,992.996
46	391,311.138	581,992.066
47	391,310.380	581,991.136
48	391,309.622	581,990.205
49	391,308.864	581,989.275
50	391,308.103	581,988.341
51	391,307.345	581,987.411
52	391,306.587	581,986.480
53	391,305.829	581,985.550
54	391,305.071	581,984.620
55	391,304.313	581,983.689
56	391,303.555	581,982.759
57	391,300.900	581,982.817
58	391,299.303	581,982.711
59	391,297.707	581,982.605
60	391,296.110	581,982.500
61	391,294.514	581,982.394

Fig. 2. *Pattern for the consolidation with drilled piles*

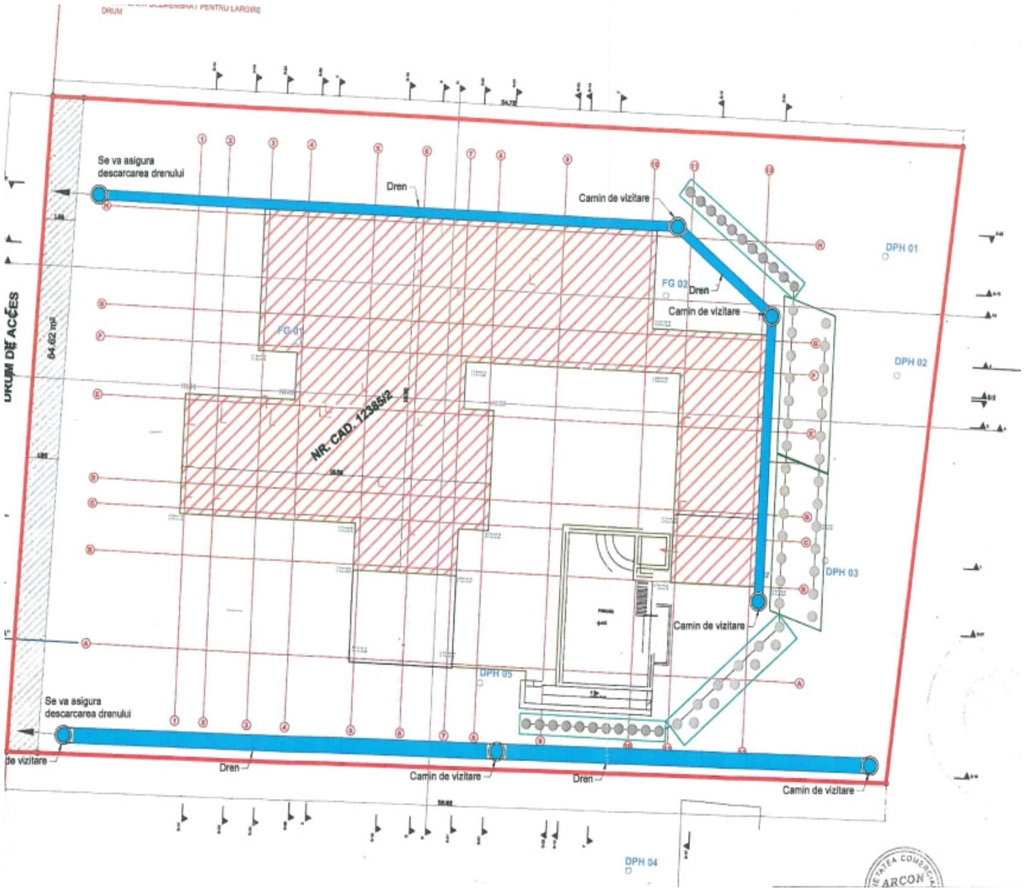


Fig. 3. *Drainage system plan*

5. Conclusions

The presented landslide occurred during the excavations for a new building construction. The surrounding area was showing signs of water accumulation in soil and swamp vegetation. Due to the small slope on the site the landslide risk analysis was never a major priority in the design project.

The main cause of the landslide was the excavation with a big slope that easily activated the instability and the phenomena was extended to the areas nearby not only on a small area near the excavation. The underground water current had also a major impact in the activation of the landslide.

Some earthworks need more attention from design to build and are not over conservative to look and overlook at the possible problems that could occur on the site.

Due to the landslide activation the building cost over exceeded the initial estimation and now the whole process is stopped.

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