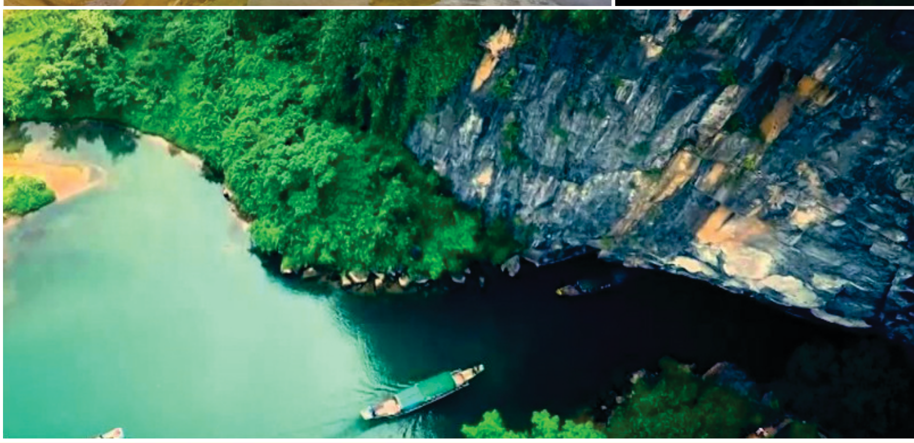
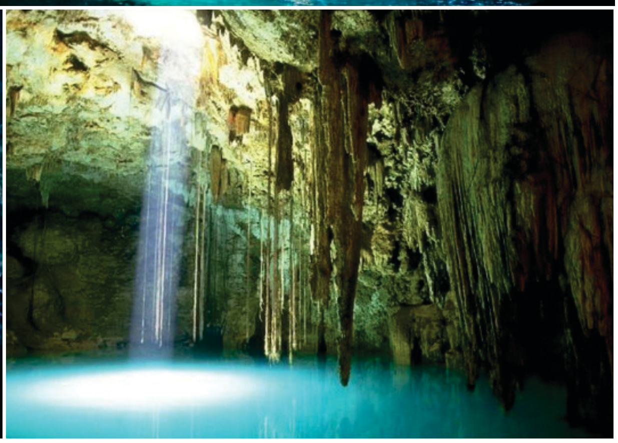
PROCEEDINGS OF THE 4th INTERNATIONAL CONFERENCE
VIETGEO 2018, QUANG BINH, 21-22 SEPTEMBER, 2018

GEOLOGICAL AND GEOTECHNICAL ENGINEERING IN RESPONSE TO CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT OF INFRASTRUCTURE





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Quang Binh, 21&22 September 2018

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Organized by

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CAUSES OF LANDSLIDE IN THE ONG TUONG HILL AREA, HOA BINH CITY AND TREATMENT SOLUTIONS

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Abstract: The headquarters of the Provincial Party Committee and the People's Committee of Hoa Binh Province are built at the foot of Ong Tuong hill. During the construction process, the construction unit has dug into the hillside to create the construction site and build the retaining wall system. Climate change and the status of exploitation and deforestation of tropical forests in order to make flood situation more serious. During the rainy season in 2017, especially from September to October, Hoa Binh area had heavy rain for a long time, making the soil saturated with water, increasing its gravity, reducing the cohesion and slide resistance, leading to the landslide. In Hoa Binh city, landslide occurred in three areas: East of Ong Tuong Hill, Thai Binh Ward and Cham Mat Ward. We analyzed the survey data and test results to determine the cause of landslide in Ong Tuong hill. From the current situation and the causes of the landslide, we have proposed the treatment solutions for sliding mass.

Keywords: landslide; large diameter well; Hoabinh; Vietnam.

1. Introduction

In Hoa Binh province and other neigh boring areas, studying geological hazards in general as well as landslides in particular has always been an urgent issue in recent years. At the provincial level, there were studies by authors such as Nguyen Ngoc Thach, et al (2002), Dinh Van Toan, et al (2006). Landslide occured along major roads in the province and other places were also mentioned in the studies by Vu Van Chinh, et al. (2011); Cao Dinh Trieu, et al. (2012). In addition, landslide studies and the installation of a landslide monitoring system and proposed treatment solutions have also been applied to some sliding mass in the Hoa Binh area, which are mentioned in study by Nguyen Quoc Thanh et al., 2008.

2. Geotechnical conditions of study area

2.1. Location

Hoa Binh city is about 76 km west of Hanoi. The boundary of Hoa Binh city: The north borders Thanh Son district (Phu Tho province), Ky Son and Kim Boi districts in the east, Cao Phong district in the south, Da Bac district in the west. Ong Tuong hill is located in Phuong Lam Ward, Hoa Binh city, Fig 1.

Fig. 1. Location of study area

2.2. Geological feature of study area

2.2.1. Formations

According to the survey results of the geological map of the scale 1/500 of the survey area, refer to the geological map at the rate of 1/200,000; 1/25,000 in the area, the study area has the following formations:

1. Ban Diet formation ($C\text{-}P_2bd$)
2. Vien Nam Formation (T_1vn)
3. Dong Giao Formation:
- Lower sub-formation ($T_2ađg_1$)
- Upper sub-formation ($T_2ađg_2$)
4. Song Boi formation:
- Lower sub-formation ($T_{2\text{-}3}sb_1$)
- Upper sub-formation ($T_{2\text{-}3}sb_2$)
5. Quaternary Formations (a,e,d,pQ_1v), Fig 2,3.

Fig. 2. Deluvi zone

Fig. 3. Proluvi zone

2.2.2. Faults

The faults in the study area from Ong Tuong Hill extend south to the Cun slope, in the southern part of the fault zone located to the west of the Hoa Binh depression. In this section, five parallel faults were investigated in detail, Fig 4.

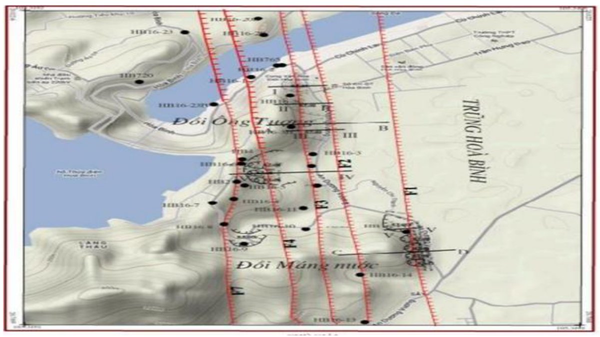

Fig. 4. Location of faults in the study area

2.2.3. Weathering

Based on the map of weathering and Quaternary sediments of Vietnam 1: 1,000,000 by Ngo Quang Toan (Editor), 2000 and other documents, in Hoa Binh province, there are 4 types of weathering: Ferosialite , Sialferite, Seralite and Saprolite.

2.2.4. HydroGeology

Groundwater in the study area exists in two water complexes:

- Complex of water in the fractured rocks, water is not rich, mainly phreatic water.

- Complex of water in Quaternary sediments, usually contained in sandy and sandy layers. The groundwater level is 0.5 ÷ 1.5m from the ground and usually fluctuates in season.

2.2.5. Strata and physical-mechanical properties of soil and rock

In the area of landslide in the east of Ong Tuong hill, we have collected the geological survey data. From the survey results, we determined the strata in the study area as follows:

- Layer KQ: This layer is unevenly distributed. The average thickness of the layer is 4.4m. The composition of the layer is Sandy clay content grit, firm (R_o = 1.09 kG/cm^2; E_o = 60.64 kG/cm^2).

- Layer 1: Sandy clay, brownish gray, content grit, stiff. This layer is under the soil layer of KQ, distributed throughout the survey area. The average layer thickness is 4m. (R_o = 0.88 kG/cm^2; E_o = 46.72 kG/cm^2, when saturated).

- Layer 2: Yellowish-gray clay, stiff. This layer is under layer 1, widely distributed throughout the survey area. The average thickness of the layer is 14.7m. This is the product of the weathering process from the original rock (R_o = 1.36 kG/cm^2; E_o = 56.20 kG/cm^2, when saturated).

- Layer 3: Clay, yellowish gray, very stiff. This layer is under layer 2. The average thickness of the layer is 13.8m. This is the product of the weathering process from the original rock (R_o = 1.48 kG/cm^2; E_o = 95.80 kG/cm$^{2+,}$ when saturated).

- Layer 3a: Clay, gray, very stiff. This layer is under layer 2. The average thickness of the layer is 9.5m. This is the product of the fault operation (R_o = 1.95 kG/cm^2; E_o = 198.9 kG/cm^2).

Layer 3b: Sandy clay content grit, yellowish gray, very stiff. This layer is under layer 3a. (R_o = 1.95 kG/cm^2; E_o = 182.5 kG/cm^2).

- Layer 4a: Claystone, siltstone, medium weathered, fine-grained, dark gray, brownish gray, sometimes rocks weathered into grit content clay. This layer is widely distributed in the study area (C_o = 102 kG/cm^2, when saturated).

- Layer 4b: Claystone, siltstone, slight weathering, mass structure, fine grain, dark gray.

- Layer 5a: Limestone, brownish gray, strong weathering and cracking (C_o = 185 kG/cm^2, when saturated).

- Layer 5b: Limestone, white gray, moderate weathering and cracking, mass structure, fine grain (C_o = 291 kG/cm^2, when saturated).

- Layer 6a: Basalt stone, brownish gray, mass structure, distributed over the top of Ong Tuong hill. Rock is an eruption product and lies unconformably with two layers above (C_o = 167.5 kG/cm^2, when saturated).

- Layer 6b: Basalt stone, dark gray, mass structure, distributed over the top of Ong Tuong hill. Rock is an eruption product and lies unconformably with two layers above (C_o = 386 kG/cm^2, when saturated).

3. Status and causes of landslide in study area

3.1. Status of landslide in Ong Tuong Hill area

Field survey has identified 8 land slide points, including 2 large-scale points; 4 points of medium scale and 2 points of small scale. Land slide points occur in the talus of the roads or talus after the construction or houses, Fig 5,6, Table 1.

Fig. 5. Landslide points in Hoa Binh

Tab. 1. Statistics on the number of land slide by scale, sloping type and land use status of Hoa Binh city [3]

Scale	Total	Slope		Land use status			
		Natural	Artificial	Population	Mining	Cultivation	Forestry
Small	2		2	2			
Medium	4		4				6
Large	2		2				
Very large							
Extreme large							
Total	8		8	2			6

From the above table, we notice that landslides mainly occur in artificial slopes, near residential areas. Landslide are mainly due to human activities such as digging slopes to make roads and other structures.

Fig. 6. Landslide points in Hoa Binh city

Headquarters area of Hoa Binh People's Committee is located on the east side of Ong Tuong Hill. After heavy rains for a long time, on the night of October 9, 2017, there were 18 cracks on slopes of 2 to 15 cm in width and 10 to 90 meters in length; At the same time, a sliding surface of over 300 m in length, 200 m in width, 30 m in depth is formed. The sliding mass is estimated at 1.8 million m^3 has been moved downward with a displacement of 5 to 80 cm, Fig 7-10.

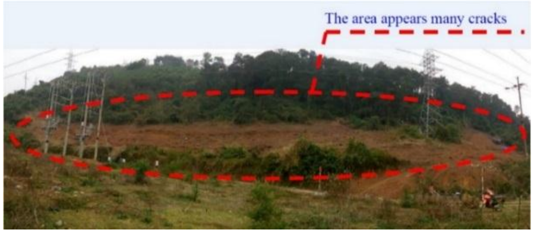

Fig. 7. The status of landslide area in the east of Ong Tuong hill

Fig. 8. Landslide at the entrance of the People's Committee

Fig. 9. Cracks on road 7 behind the substation

Fig. 10. Cracks on the hill behind the People's Committee building

3.2. Slope stability calculation using Geoslope software

Calculation of landslide during rainy season, when saturation line is rising, time of occurrence of landslide (The saturated line is determined from observation time in August, 2017). Calculations using GEOSLOPE software, Table 2,3, Fig 11-15.

Tab. 2. Input parameters for calculation model

Layer	γ_{sat} (kN/m^3)	c (kN/m^2)	φ (Degree)
KQ	18.7	15.6	$12^0$11'
1	17.9	14.8	$11^0$20'
2	18.6	19.7	$14^0$36'
3	19.3	22.4	$13^0$21'
3a	19.4	22.4	$13^0$21'
3b	22	27.6	$19^0$06'
4a	26.2	50	25^0
5a	26.2	50	25^0
5b	26.8	50	25^0
6a	26.4	100	35^0
6b	26.8	100	35^0

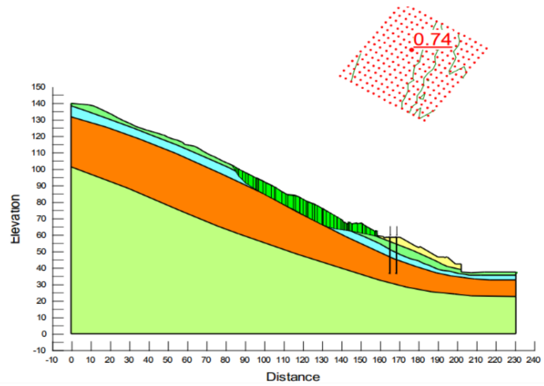

Fig. 11. Result of stable calculation at cross section 1

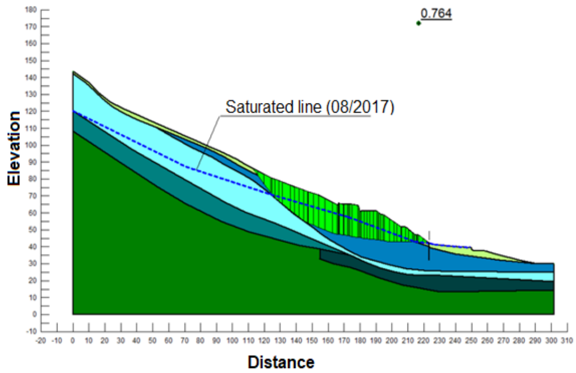

Fig. 12. Result of stable calculation at cross section 2

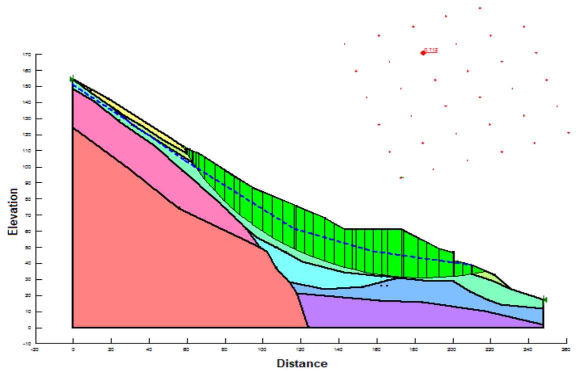

Fig. 13. Result of stable calculation at cross section 3

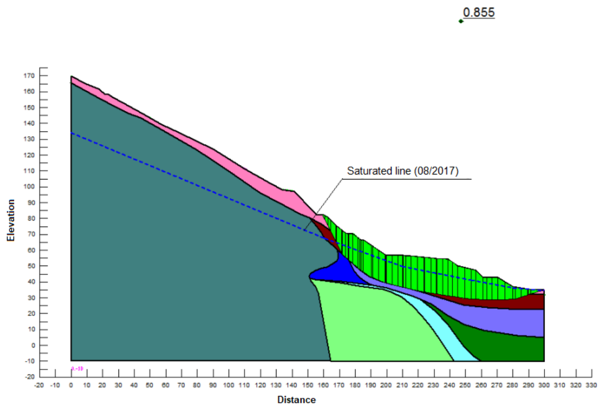

Fig. 14. Result of stable calculation at cross section 4

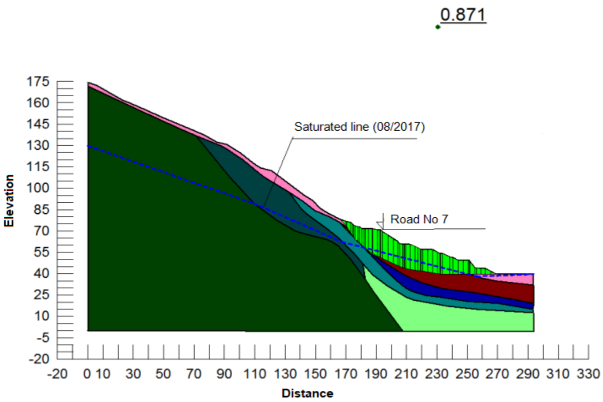

Fig. 15. Result of stable calculation at cross section 5

Tab. 3. Summary table of stable calculation results

Section	K	[K]	Evaluation
Section 1	0.74	1.035	Unstable
Section 2	0.76	1.035	Unstable
Section 3	0.71	1.035	Unstable
Section 4	0.86	1.035	Unstable
Section 5	0.87	1.035	Unstable

General safety coefficients of works and work items (refer to QCVN 04-05 / 2012 / BNNPTNT).

- For the basic load combination: [K] = 1.15
- For special load combinations:
$[K]_S = [K] * nc = 1.15 * 0.9 = 1.035$
- For construction load combination:
$[K]_S = [K] * nc = 1.15 * 0.95 = 1.093$

The calculation results show that the calculated sections are unstable in saturation condition, which is perfectly suited to the landslide status, so the treatment is very necessary and urgent.

3.3. Causes of landslide in Ong Tuong Hill area

3.3.1. Analysis of topography change

In order to evaluate the topography of the area, we used the survey topography in 2007 to compare with the survey data in January 2018, Fig 16-18.

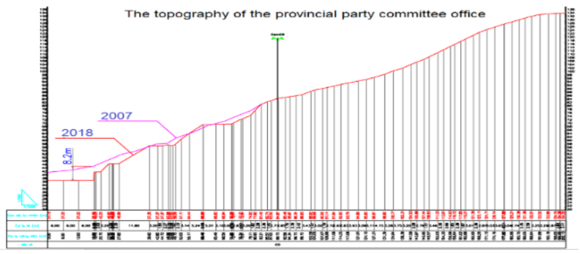

Fig. 16. Cross section of the provincial commission office area in 2007 and 2018

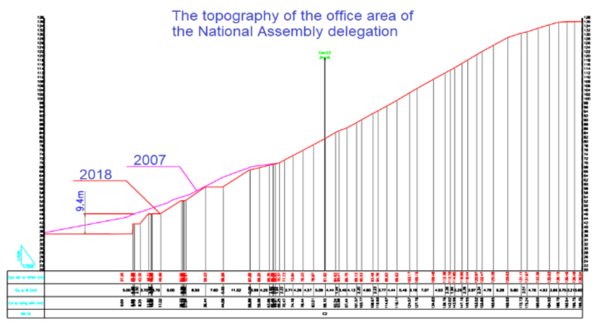

Fig. 17. Cross section of the National Assembly delegation office in 2007 and 2018

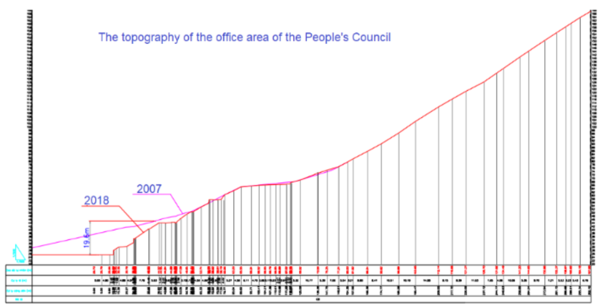

Fig. 18. Cross section of the People's Council Office 2007 and 2018

Results of research on the topography before and after construction, some infrastructure works on the foot of Ong Tuong hill has excavated into the foot of hill, taking a lot of construction site, especially the area behind the headquarters Provincial People's Council has dug up to 20m.

3.3.2. Analysis of strata and physical-mechanical properties of soils and rocks

Geological features of the area are very complex, the strata changes continuously, the composition of the soil is not uniform. In addition, there are some broken zones formed by the tectonic process.

Ground structure has many types of soil and rock with different composition and weathering, not changing according to the rules. These layers may be of different geological formations. The thickness of the cover layer is quite large but changes continuously; The groundwater level depends on the seasons, at about 4-5m depth in rainy season. Particularly, when rain is in the long time, the soil in the cover may be completely saturated. Experimental results of soil samples in saturated state showed that low friction angle and low cohesion are the main cause of landslide in the rainy season.

Under the cover layer is a medium to strong weathered zone. The rocks and soils are in saturated state resulting in reduced shear strength. In addition, it can also create underground flows.

Conclusion: From the analysis of survey data and calculation results, we have identified the main causes of land slide in the study area as follows:

- During construction at the foothill, the slope has been dug for construction, changing the natural equilibrium of the soil.

- The area has thick cover, rock and soil have weak mechanical properties, soils have high porosity, great permeability increases self weight and reduces sliding resistance.

- Due to climate change, in 2017, in the study area, there has been heavy rain for a long time, causing the soil to become saturated. Heavy rains also cause soil erosion at the top of the slope and lead to landslide.

4. Proposal of the solutions for landslide treatment

Two solutions have been proposed to treat the landslide in the area:

Solution 1:

- Slope treatment by grade down the slope to reduce the load and construction of bored piles D1000;

- Surface water drainage by covering waterproof HDPE membrane on the ground to slope’s cover and collecting surface water into the sewer system; treatment of surface cracks by opening cracks and filling with compacted clay K = 0.95; combine grass planting in reinforced concrete frame to protect HDPE membrane and create landscape;

- Collection and drainage of underground water by self-flowing horizontal well system, at the foot of the retaining wall (altitude + 40.0 m) and natural slope (altitude 86.5 m).

Solution 2:

- Slope treatment by grade down the slope to reduce the load and use cable anchor system;

- Surface water drainage by covering waterproof HDPE membrane on the ground to slope’s cover and collecting surface water into the sewer system; treatment of surface cracks by opening cracks and filling with compacted clay K = 0.95; combine grass planting in reinforced concrete frame to protect HDPE membrane and create landscape;

- Collection and drainage of underground water by self-flowing horizontal well system, at the foot of the retaining wall (altitude + 40.0 m) and natural slope (altitude + 86.5 m).

The above mentioned solutions have the following difficulties and limitations:

- For drainage solution in combination with concrete cover, grass planting on the sloping surface: this solution only restricts rainwater into the aquifer but does not lower the ground water level in the slope.

Therefore, to ensure the technical, it is necessary to design underground drainage system, which is costly and not economical.

- The solution is to install horizontal water pipes in slope, due to small diameter and limited length, so it is easy to clog and reduce drainage capacity, the efficiency of lowering the ground water is low. In this case, due to the large slide and high ground water level, the reduction of the sliding force by drainage is more important than the increase the sliding resistance with structural support solutions (such as retaining walls, anchor or concrete nail).

- Therefore, there must be a solution that both reduces the sliding force (underground drainage) and increases the sliding resistance (by using large diameter piles). To improve efficiency, we propose solutions of large diameter drainage wells based on the principle of both surface and ground water drainage and increase sliding resistance. The efficiency of the solution was analyzed using Geoslope software, Fig 19-22.

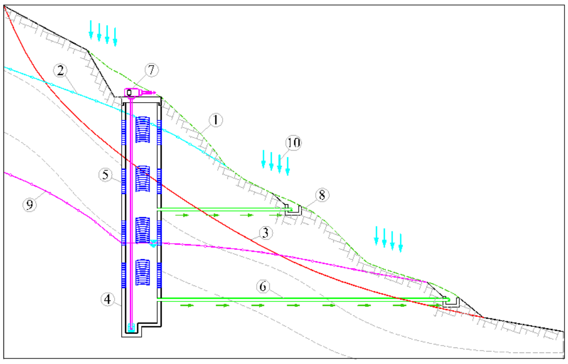

Fig. 19. Structure of large diameter wells

1. Natural slope; 2. Underground water level in slope; 3- Assumed slope; 4- Reinforced concrete well; 5- Water collection window (with filter); 6- Horizontal drainage pipes; 7- Spare pump; 8. Surface water drainage chanel; 9. Ground water level when the well is operational; 10. Rainwater.

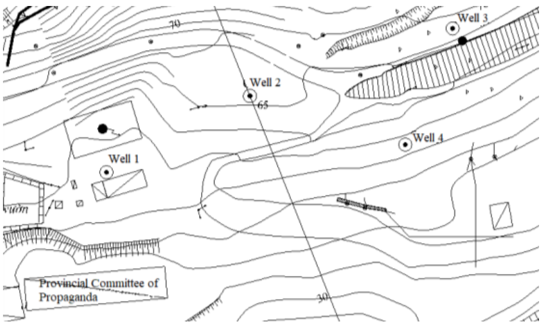

Fig. 20. The layout of the well on the slope

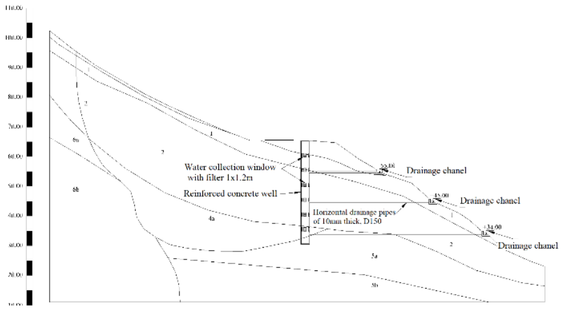

Fig. 21. Design section of large diameter wells

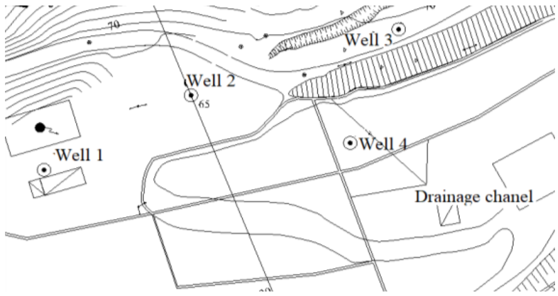

Fig. 22. The layout of the drainage system

5. Stable calculation using Geoslope software.

The results of calculation have shown in Table 4 and Fig 23.

Tab. 4. Input parameters for calculation model

Layer	γ_{Sat} (kN/m^3)	c (kN/m^2)	φ (degree)
KQ	18.7	15.6	$12^0$11'
1	17.9	14.8	$11^0$20'
2	18.6	19.7	$14^0$36'
3	19.3	22.4	$13^0$21'
3a	19.4	22.4	$13^0$21'
3b	22	27.6	$19^0$06'
4a	26.2	50	25^0
5a	26.2	50	25^0
5b	26.8	50	25^0
6a	26.4	100	35^0
6b	26.8	100	35^0
Concrete	25	2000	45

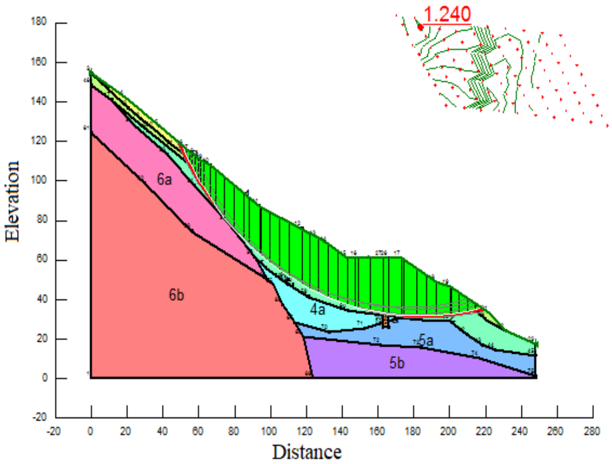

Fig. 23. Slope stabilization results when large diameter wells are applied at section 3 with K = 1.24.

5. Conclusion

The research has assessed the land slide in Ong Tuong hill area, assessing the impact of this phenomenon on the construction works.

Using the numerical modeling method, the team assessed the stability of the slope under current conditions. The results show that at all computational slopes, the slope is in a state of instability, which is consistent with the current situation in the area.

The research team has also proposed a solution to ensure slope stabilization, designed and calculated slope stability when applying this solution. As a result, the stability of the sloping roof increased, the slope stabilized.

.

Nomenclature

The following symbols are used in this paper:

c = cohesion, kN/m^2

E_o = deformation modulus, kN/m^2

R_o = conventional bearing capacity, kN/m^2

γ_{Sat} = saturated unit weight of material, kN/m^3

φ = inner friction angle, ^{o}

K = calculated safety factor

[K] = allowable safety factor

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