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IMPROVEMENT OF SLOPE STABILITY IN THE CAMPING FACILITIES OF "ELPIS" IN ANO POROIA OF SERRES, IN GREECE

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ABSTRACT

The present paper considers the landslide took place in early June 2009 on the slope of the input of camping facilities "Elpis" in Ano Poroia of Serres, in Greece and proposes measures to treat this slope. Specifically, there is a specific reference to the program Slide v6.0, which is used for the simulation of the landslide in the study area. The results are extracted by taking into account the geological conditions of the study area, the morphological conditions of the area, where the camping facilities are, the climatic characteristics of the region and the seismicity. The models which were resulted by the program Slide v 6. 0, are cited and evaluated. Moreover, specific countermeasures are proposed for the improvement of the slope stability.

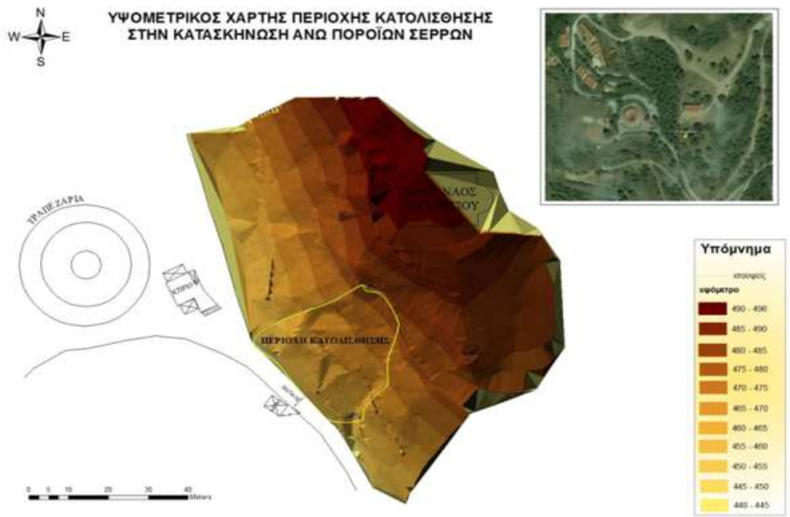
KEYWORDS: Countermeasures, Simulation on Program Slide v6.0, Slope Stability

INTRODUCTION

The procedure followed in order to execute the whole research is the following: initially an autopsy was necessary in the area where the landslide occurred, with in situ observation of the slope and assessment of the overall situation in the area of camping facilities and the surrounding area. Also, it was necessary the outdoor work with taking measurements using a geological compass on the surfaces of discontinuities of the mica schist on either side of the landslide, to determine their orientation. At next step, the analysis of the slope stability took place, in order to determine the failure mechanism, considering the mechanical parameters of the materials that compose the slope. These data were applied to the computer program Slide v6.0 (Rocscience Education Program), for a back analysis, to identify the factors that led to the landslide. The results were evaluated in order to suggest specific countermeasures for the improvement of the slope stability.

DESCRIPTION OF THE LANDSLIDE

The landslide took place in June 2009, on the slope in front of the entrance to the camping facilities of the Christian Brotherhood "Elpis", in Ano Poria of Serres. The slope, which presented the failure, is 33m high, with $250^o/40^o$ orientation. The slope is located down-slope of the Church of St. George, right of the road leading to the entrance of the camp (northwesterly direction), as shown in the following elevation map (map 1). This slope is composed of mica schist, forming a part of the upper course of the crystalloschistic of Serbomacedonian, Vertiskos (Mountrakis D, 2010), combined with soil weathering material (with presence of clay material) mounted on the shale rock. The length of the maximum cross section of the landslide is 30m and the volume of landslide material was high, as illustrated in image 1, covering the access road to the camp, and then removed to improve the access.



Map 1: The Elevation Map of Landslide in the Area of Camping Facilities 'Elpis'. (Made by Using the Arc G is Computer Program). (The Topography Refers after the Event of the Landslide). The Upper Right Corner Shows the Wider Area in the Camping Facilities, (By Google Earth)

Image 1: The Foot of the Landslide at the Entrance of the Camp. The Material of the Landslide Consists of Big Volumes of Mica Schist Combined with Soil Weathering Material

Image 2: The Church of St. George in 25m from the Upper Limit of the Landslide

The landslide occurred after a period of heavy rain and an earthquake of 5.1 Richter on 24 May 2009, centered 24 km west of Ano Poroia, north of Lake Doirani on the border of FYROM, following an intense aftershock activity with earthquakes up to 4.8 Richter. All these conditions had exacerbated the situation of the slope, which was already in a limit equilibrium, as shown in the following stability analysis. Therefore, the aim is to analyze the stability of the existing slope and suggest appropriate measures to deal with the landslide, so as to reduce the landslide risk in an area of particular importance, because of the existing camping facilities, 25m from the upper limit of the landslide there is the church of St. George. Furthermore, it is worth noting that downstream of the road within 25m there are private residences.

Slope Stability Analysis

Analyzes were performed with the computer program Slide v6.0, in order to determine the slip surfaces into the soil material. These analyzes were performed for both dry and wet conditions, with seismic load and in static conditions (Rocscience Inc, 2004). Initially the slope was in limit equilibrium with a factor of safety, FS = 1.01. It is found that the landslide in the weathering soil material, was triggered by heavy rain that occurred in June 2009, and the factor of safety is drastically reduced below the FS = 0.70. The low resistance and the difficulty in draining of clay, resulted in the instability of the slope, which was already in limit equilibrium. Additionally, the seismic activity which occurred in late May 2009, with an earthquake of 5.1 Richter, 24km west of the study area and north of the Lake Doirani, probably led to an initial disintegration of the material. The factor of safety in dry conditions with the seismic load, is FS = 0.83. The mechanic parameters were determined empirical not only for the soil material but also for the rock mass (the mica schist), because of the lack of execution of boreholes. The mechanic parameters c (cohesion) and φ (friction angle) (Dimopoulos G, 2008, Koukis G, Sampatakis N, 2002), were calculated by the computer program RocLab, taking into account the quality of the rock mass. The Geological Strength Index of the rock mass (Hoek and Marinos , 2000) was determined low, GSI= 33-37 (very blocky-poor quality of the discontinuities). The Uniaxial Strength is considered low as 35. It is noticed that Spencer's method is used as a method of analysis, because this method takes into account the normal and shear stresses, and is the most valid method about a completed static solution (Krahn J, 2004).The following figures show the models that extracted by the program Slide v6.0 (Rocscience Education Program).

- **Static Conditions (Dry)**

Material	Unit Weight γ (kN/m^3)	Cohesion c (kN/m^2)	φ (°)	Factor of Safety (Spencer's method)
Soil weathering material	20	5	28	1.01

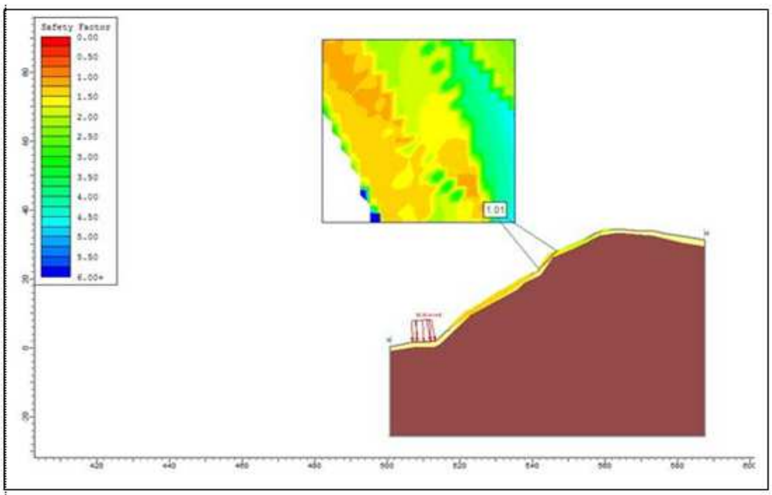


Figure 1: The Slip Surfaces with the Lowest Factor of Safety in Static-Dry Conditions (The Yellow Color Displays the soil Material Mounted on the Mica Schist-Brown Color)

- **Static Conditions (Wet, with Pore Pressure)**

Material	Unit Weight γ (kN/m³)	Cohesion c (kN/m²)	φ (°)	Coefficient Ru	Factor of Safety (Spencer's method)
Soil weathering material	20	5	20	0.2	0.70

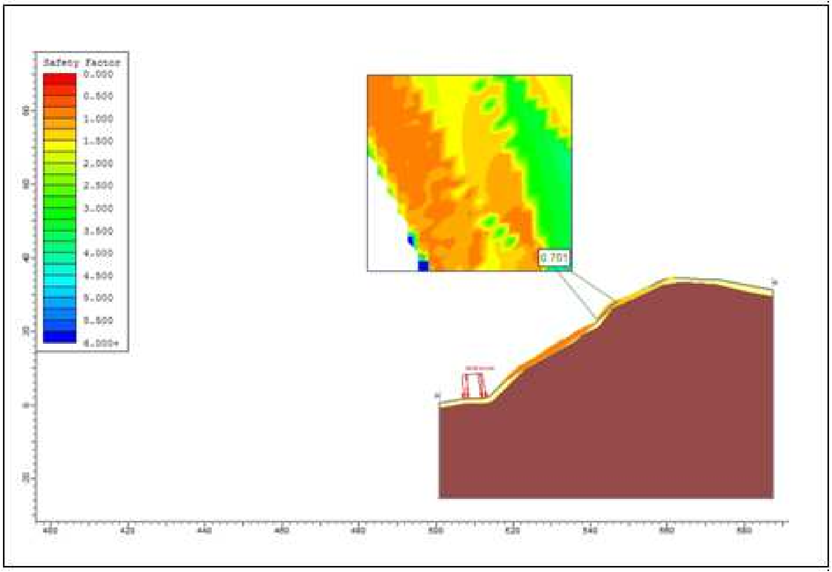


Figure 2: The Slip Surfaces with the Lowest Factor of Safety in Static- Wet Conditions. (The Yellow Color Displays the Soil Material Mounted on the Mica Schist-Brown Color)

- **Dynamic Conditions (Dry)**

Material	Unit Weight γ (kN/m³)	Cohesion c (kN/m²)	φ (°)	Factor of Safety (Spencer's method)
Soil weathering material	20	5	28	0.83

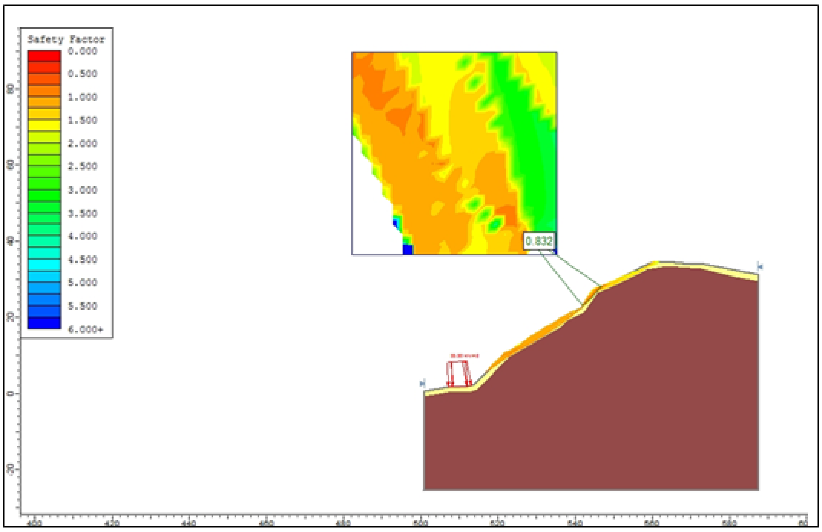


Figure 3: The Slip Surfaces with the Lowest Factor of Safety in Dynamic- Dry Conditions. (The Yellow Color Displays the Soil Material Mounted on the Mica Schist-Brown Color)

Dynamic Conditions (Wet, with Pore Pressure)

Material	Unit Weight γ (kN/m^3)	Cohesion c (kN/m^2)	φ (°)	Coefficient Ru	Factor of Safety (Spencer's method)
Soil weathering material	20	5	20	0.2	0.57

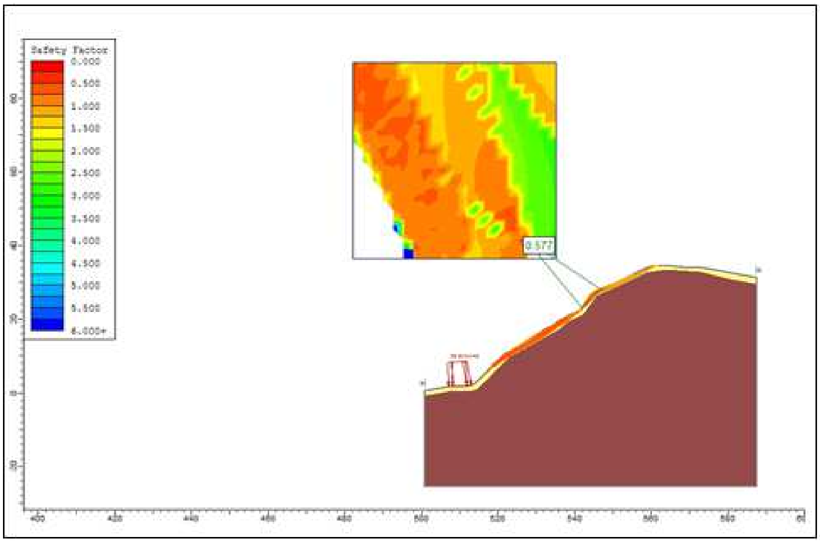


Figure 4: The Slip Surfaces with the Lowest Factor of Safety in Dynamic-Wet Conditions. Yellow Color Displays the Soil Material Mounted on the Mica Schist-Brown Color)

On either side of the landslide, were taken measurements with a geological compass, in order to determine the orientation of the discontinuities of the mica schist. After the elaboration of these measurements by plotting the discontinuities on the program Dips, were observed possible failures (Dimopoulos G, 2008). This limit equilibrium can easily be disrupted after an intense and prolonged rainfall, or an earthquake activity. The failures that can be occurred are: plane failure relative to the schistosity and wedge failure relative to the pair of discontinuities of schistosity and J1 (figure 5). The discontinuities in whole are opening 1-3mm, filled with clay material, which prevents the drainage of water, thereby reducing the shear strength, having an impact on the stability of the slope (Christaras V, 2005, Tsotsos S, 1991,).

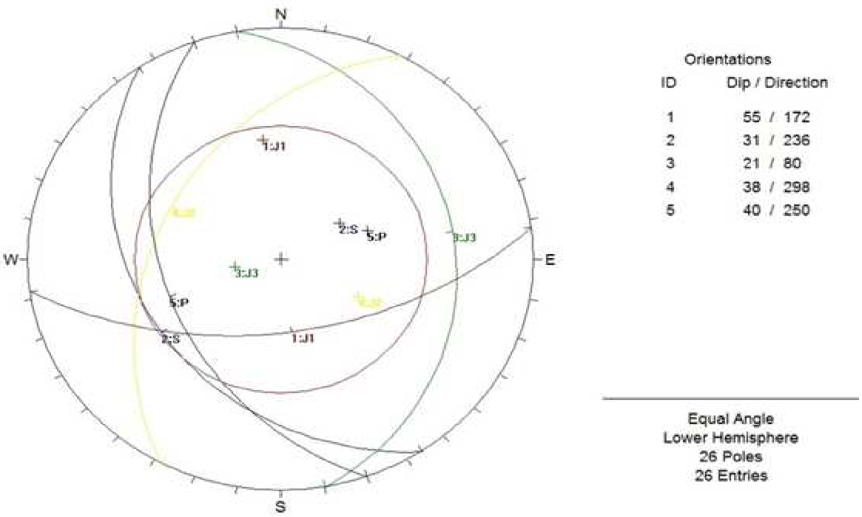


Figure 5: Chart with the Projection of the Orientation of Discontinuities in Mica Schist

Image 3: The Mica Schists Right from the Eastern Boundary of the Landslide (in Detail the Discontinuities)

Counter Measures

The critical situation of the slope requires appropriate measures to stabilize it, in a significance area, where there are camping facilities, a church in the upstream and private residences in the downstream, at 25m. First of all, it is proposed the removal of soil material and the flattering of the slope by forming three terraces, with a tilt of 36^o (OMOE, Vol 11). Furthermore, the installation of wire mesh in the slopes is important, in order to retain the big volumes of the mica schist, and the development of a network of drainage ditches to remove the rainwater, so as to avoid the local development of moisture in the rock mass (Davos, 2001, Koukis G, Sampatakis N, 2002). It is also necessary the installation of horizontal drainage holes into the rock mass, to relieve the pressure of the water within the rock mass (figure 6). Finally, if there is a great thickness of loose deposits and poor quality of the rock mass beneath the soil material (in case of executing boreholes in order to determine this situation), it is proposed a second scenario for a further improvement of the stability. Considering the protection of passing people, the camping facilities and the houses, it is recommended the installation of anchored wall 3m high, on the foot of slope and the inclined portion of the second terrace. It is also recommended series of anchors at a similar grid for retaining the volumes of mica schist (figure 7). The average of cost in the first scenario is estimated at 402.898,31 €, while in the second scenario the cost is increased to 507.475,51 €, due to the use of more cubic concrete for the installation of anchored wall.

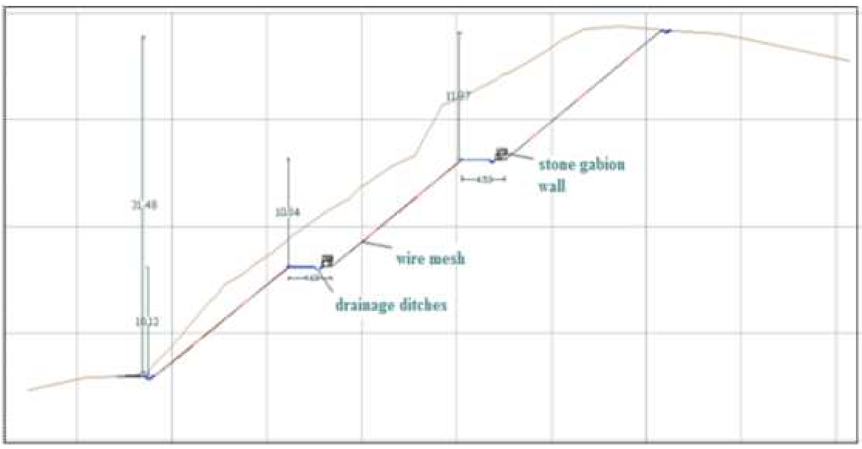


Figure 9: The Existing Slope (Brown Line), the Proposed Terraces with Tilt 36^o Tilt (Red Line), and the Additional Counter Measures Proposed (Drainage Network, Wire Mesh, Stone Gabions)

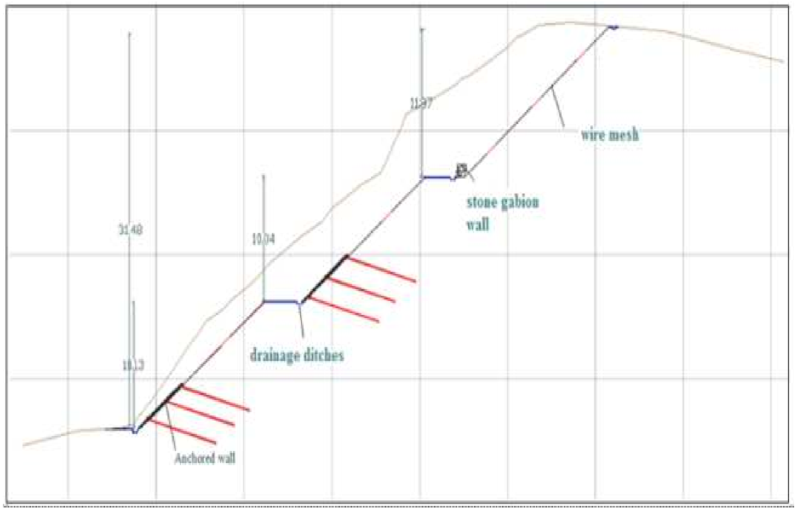


Figure 10: The Existing Slope (Brown Line), The Proposed Terraces with 36^o Tilt (Red Line), and the Additional Counter Measures Proposed (Anchored Wall, Drainage Network, Wire Mesh, Stone Gabions)

CONCLUSIONS

The landslide in the weathering soil material, which took place on the slope at the entrance of the camping facilities "Elpis", in Ano Poroia of Serres, was triggered by heavy rain in early June 2009. The low resistance and the difficulty in draining of clay, resulted in the instability of the slope, which was already in limit equilibrium (FS=0.70). Moreover, the seismic activity which occurred in late May 2009, with an earthquake of 5.1 Richter, 24km west of the study area and north of the Lake Doirani, probably led to an initial disintegration of the material, underestimating the Factor of safety (FS=0.83). The seriousness of the situation in the study area, demands further actions in order to encounter the whole situation. First of all, terraces with tilt of 36^o are proposed, a drainage network, wire meshes, gabion walls. Additionally, anchored walls in the first two terraces are necessary for further strengthening of the slope, if there is a great thickness of loose deposits and poor quality of the rock mass (defining by the execution of boreholes), beneath the weathering soil material.

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